USING FUZZY LOGIC P. 32

IEEE
SPECTRUM

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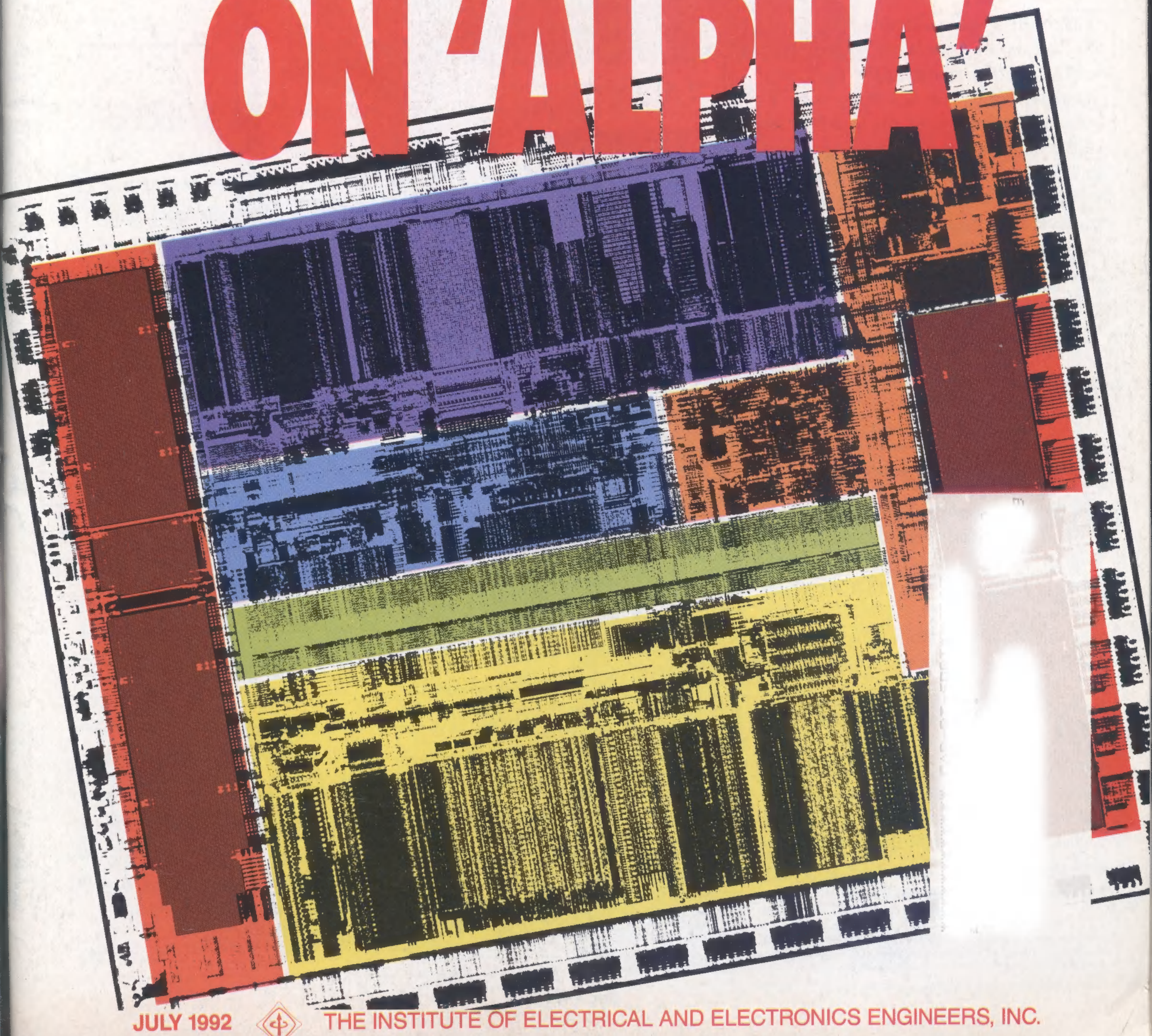

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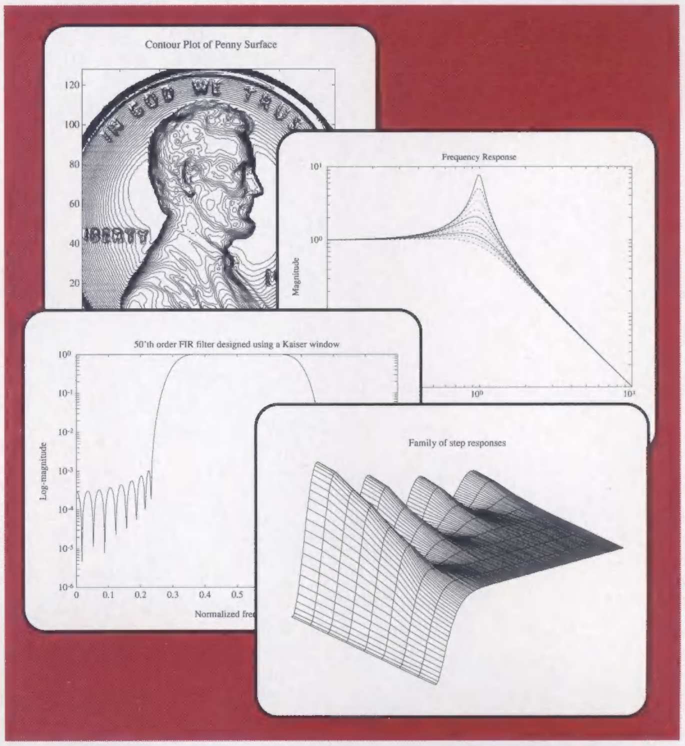

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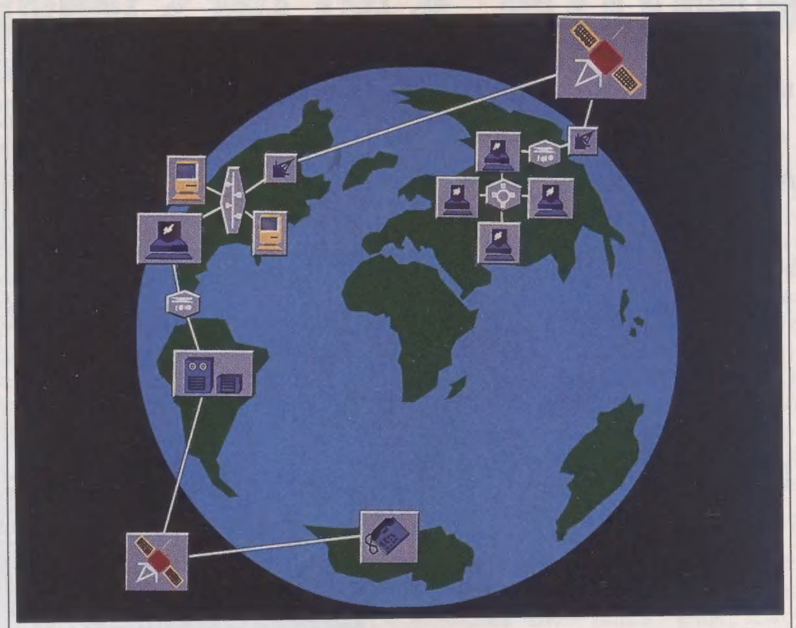

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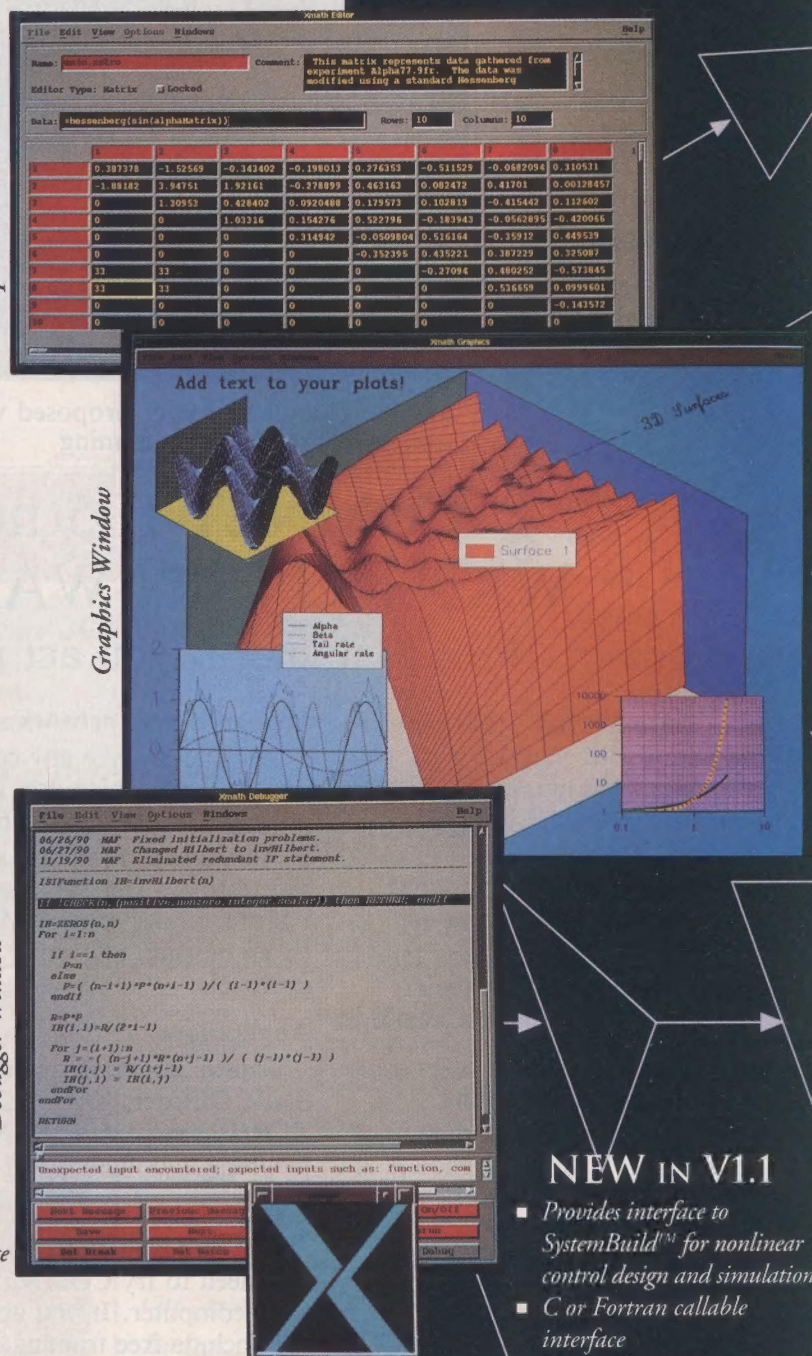

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Newslog

MAY 11. **General Motors Corp.'s Hughes Aircraft Co.,** Los Angeles, said it had agreed to buy the missile business of **General Dynamics Corp.,** Falls Church, Va., for stock worth at least US $450 million. The deal puts Hughes neck and neck with its chief rival, **Raytheon Co.,** Lexington, Mass., as the nation's largest missile maker.

MAY 13. The **National Aeronautics and Space Administration** said that three astronauts had ventured into space from the space shuttle **Endeavour** to grab an Intelsat communications satellite by hand, wrestle it into the shuttle's payload bay, and strap on an engine to send it into its proper orbit later. It was the first time so many astronauts had walked in space together and the first time anyone had captured an orbiting satellite manually.

MAY 14. **Echo Logic,** an AT&T Bell Laboratories' subsidiary in Holmdel, N.J., said it is working with **Apple Computer Inc.,** Cupertino, Calif., on a software tool that speeds the transfer of programs made for one computer architecture to another. Called FlashPort, the program cuts down the programmers' translation time from 8–12 months to two weeks.

MAY 18. **McCaw Cellular Inc.,** Kirkland, Wash., and **Oracle Systems Corp.,** Redwood Shores, Calif., said they had joined with **Omnipoint Data Co.,** Colorado Springs, Colo., to develop a service that within two years could begin low-cost broadcasts of a wide variety of digital information, including electronic newspapers, government documents, textbooks for universities, and computer video. Technology from Omnipoint will piggyback the service's signal on top of existing radio signals to transmit data far faster than telephone lines or current wireless systems.

MAY 26. **AT&T Co.** said it had hired more than 100 scientists in optical-fiber research from the **Russian Academy of Sciences** in Moscow. They will be paid their current wages—about $60 a month. **Corning Inc.,** Corning, N.Y., also said it would employ 100 Russian scientists on basic research in glass. The U.S. companies said the Russians would retain patent rights within Russia and get bonuses for outstanding work.

MAY 27. **Control Data Corp.,** Minneapolis, Minn., said it would split into two independent companies: Control Data Systems Inc. for its computer business and Ceridian Corp. for its information services businesses. The company said **Silicon Graphics Inc.,** Mountain View, Calif., had agreed to buy a 10 percent stake in Control Data Systems.

MAY 27. **Sprint Corp.,** Kansas City, Mo., announced it had agreed to buy **Centel Corp.,** Chicago, for $2.8 billion. The combined group will retain the Sprint name and will be the only U.S. company to operate in all major telecommunications markets: long distance, local services, and cellular communications.

MAY 27. The **U.S. House of Representatives** said it approved comprehensive energy legislation to overhaul electric utility regulation, promote energy efficiency, streamline nuclear plant licensing, boost the use of nongasoline fuels, and prohibit additional offshore oil drilling, except in the Gulf of Mexico and Alaska, for the next decade.

JUNE 1. **Japan's Ministry of International Trade and Industry** said it had officially closed the books on its **Fifth Generation** supercomputer project, acknowledging that its decade-long research effort had failed to displace U.S. leadership in that area. The ministry said Japan would make all the software produced by the $400 million project available to anyone for free.

JUNE 1. **American Electric Power Co.,** Columbus, Ohio, and **Intersource Technologies,** Sunnyvale, Calif., said they had developed a light bulb that uses radio waves to generate light, is more cost-effective than existing bulbs, and will last 14 years if lighted 4 hours a day. Called E-lamp, the bulb lasts at least 20 000 hours, compared to incandescent bulbs, which burn out after 1000 hours, and fluorescent bulbs that last up to 10 000 hours.

JUNE 1. **Northern Telecom Ltd.,** Mississauga, Ont., Canada, said it had received a $913 million contract from Bell Canada to supply digital central-office switches through 1993. The company said the DMS-100 switches would be built at plants in Research Triangle, N.C., and in Brampton, Ont., Canada.

JUNE 1. **Westinghouse Electric Corp.,** Pittsburgh, and **Rolls-Royce PLC,** London, said they had signed a 15-year strategic alliance to provide Westinghouse with advanced technology for new large power-generating systems and strengthen Rolls-Royce's position in industrial power generation. The partnership becomes the world's second largest power generation group, after **General Electric Co.,** Fairfield, Conn.

JUNE 2. **The Bush administration** and 16 U.S. allies on the **Coordinating Committee on Multilateral Export Controls (Cocom)** said they agreed to ease controls on telecommunications equipment meant for the former Soviet republics. Included are optical-fiber cables and transmission and switching equipment.

JUNE 4. The **Semiconductor Industry Association,** Cupertino, Calif., and the **Electronic Industries Association of Japan,** Tokyo, said they had agreed on measures aimed at increasing the sale of U.S. semiconductors in Japan this year. A key part of the plan is that Japan's 10 largest electronics companies will give U.S. and other non-Japanese suppliers advance information on their chip product needs in the third and fourth quarters.

JUNE 8. **Entergy Corp.** of New Orleans, La., announced that it would buy **Gulf States Utilities,** Beaumont, Texas, for $2.3 billion. The deal will create one of the largest electric utilities in the United States, covering five states with an area of about 29 million hectares.

JUNE 8. **Motorola Inc.'s Application Specific Integrated Circuits Division,** Chandler, Ariz., and **Mentor Graphics Corp.,** Wilsonville, Ore., said they had formed a partnership to develop a high-end, top-down application-specific IC (ASIC) computer-aided design system. Unique to the partnership is the founding of a Customer Advisory Board, whereby leading U.S. and European companies in ASIC, electronic design automation, and systems design define the scope and direction of the ASIC design system.

Preview:
JULY 20–22. The **Electronic Industries Association's Joint Electron Device Engineering Council (Jedec)** is to hold its next meeting of the **JC-42.3 Committee on RAM Memories** in Denver, Colo., to discuss the voting results of several ballots on standards for synchronous dynamic RAM packages, functions, and features. IEEE members who want to attend the meeting should contact committee chairman Jim Townsend, 714-455-2326.

COORDINATOR: Sally Cahur

JULY 1992 Volume 29 Number 7

IEEE SPECTRUM

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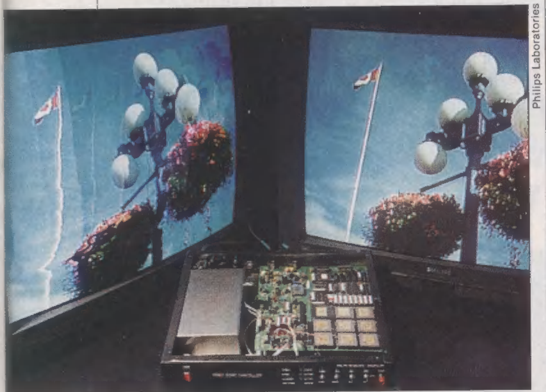

Philips Laboratories

IEEE AWARDS

Cover: Digital Equipment Corp. has unveiled the fastest-running reduced-instruction-set-computer (RISC) chip to date. The Maynard, Mass., firm hopes that, by providing software continuity with its aging VAX minicomputers as well as Unix support and future Windows NT capability, Alpha—the new RISC architecture embodied in the chip—will take it into the 21st century. To find out how Alpha was born, how it works, and how it is changing Digital, see p. 26.
Cover design: Gus Sauter.

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Forum

One bean, two beans,. . .

With reference to "The bean counters" [May, p. 18], it is unfortunate that counters do not (or cannot) realize the potential for the engineer to improve a ship's performance, both in swiftness and seaworthiness, which could result in the discovery and cultivation of a better bean.

Theodore J. Kurela
Cleveland, Ohio

Lucky's bean-counter study undeleted a file for me, dating back to my former employer, now defunct. On the day before Thanksgiving, the Chief Bean Counter caught up with me on the way to the train.

"How's your project coming, Max?," he asked, and I assured him it would be done by year's end. Milking this (rare) opportunity, I went on: "And what's the plan for next year?"

After a momentous silence, the boss replied: "Make money." I mulled that over briefly, then noted: "In that case, I hope you have ordered the plates—that's a long-lead item." Judging by the man's blank stare, I guess I was too technical.

Max J. Schindler
Boonton, N.J.

Unfairly faulted

Watson, Devaney, and Thomas's "Faults and failures" article [February, p. 54] left me cold. The authors lead us to believe that a misadjustment of 0.7 V caused 85 000 irate travelers. The article unreasonably lays blame at every point in the failure chain: "faulty maintenance, failure to follow standard practices, poor judgment, reliance on vulnerable, collocated communications links, and bureaucratic intransigence." Such a conclusion is unwarranted and leaves out the fundamental cause of this particular tragedy: poor design of the alarm system. Also, the article apparently approves of changes (the repudiation of a power-sharing agreement and the acquisition of an advanced microwave link) but fails to justify them.

First is a synopsis of the failure. The story begins with a technician misadjusting a meter relay by 0.7 V. This misadjustment prevents some diesel generators from charging the telephone company's batteries. The meter relay does raise several alarms, but these go unheeded because: (1) the audible alarm on the 15th floor is in an unattended room, (2) the maintenance staff who would have walked through the room are at a training session, (3) the wire to an audible alarm on the 14th floor had been cut, and (4) the (attended) alarm light on 14 burned out. The phone company's batteries ultimately discharge, phone service is interrupted, the air traffic controllers lose communication and consequently stop takeoffs, and 85 000 passengers are delayed.

Second is a look at these failures. The article failed to discuss whether the failure point is critical: a failure at a critical point will bring down a system. Failures at noncritical points are not newsworthy; they are expected in the normal course of operation.

The technician who misadjusted the meter relay is not at fault because the misadjustment should have been (and was) detected by other equipment. Other factors, such as a failure in the diesel generator, would also cause the meter to trip, and a reliable system would still need to detect failure. The meter-relay adjustment is not a critical point. In further defense of the technician, it is interesting to note that the misadjustment is alleged to have happened three months earlier, so the article leads us to believe that Sept. 17 was the first hot and humid day of the summer!

Management's failure to follow standard procedure—walkthrough of the building after the power switchover—is neither here nor there. A walkthrough would have detected the meter relay fault for this incident, but it would not detect other faults. If the battery-charging circuits had failed for some reason not related to a power switchover (for example, burned-out rectifiers), there would have been no walkthrough of the building, yet such a failure would discharge the batteries. The walkthrough is not critical.

The building alarms did trigger, and here is where the real blame lies. The alarm system was not failsafe, and the telephone company should know better. Instead of a red light to say failure, they should have used a green light to say AOK. If a cable gets cut or a bulb burns out, then the green light goes out and the operator knows there is a problem. The alarm is a critical point, and it must be designed well. Instead, the designers opted for redundancy (several poor alarms instead of one good one), and over time the individual systems quietly failed.

Third is the magnitude of the failure. The Federal Aviation Administration (FAA) portion of this failure is small. Although 85 000 passengers were inconvenienced, such would be the case if a heavy snow storm shut down the airports in a 330-km radius. Collocated communication links are a problem, but the FAA management knew that and apparently accepted the risk. The failure of the phone system is much more serious.

Fourth are the article's conclusions. Repudiating the load-sharing agreement with Consolidated Edison does not make technical sense because it makes the telephone system insignificantly more reliable. The agreement undoubtedly saved money for both the telephone company and the power company, so it is in the public interest. The article apparently agrees with the action, but should argue the costs vs.benefits.

Similarly, there is no cost/benefit discussion for the FAA's new communications links. The GSA bureaucracy apparently thought it was a bad idea to use Lincs; they recommended FTS-2000 instead. Although neither system was in place, this incident is now justification for (a costlier?) Lincs. Lincs might be more appropriate, but this failure is not a justification.

Finally, although the article offers an interesting description of the events, it provides a poor lesson in reliability. Instead of pointing out a technically poor alarm design, it unfairly blames maintenance, management, and bureaucracy.

Gerald Roylance
Mountain View, Calif.

Shadow play

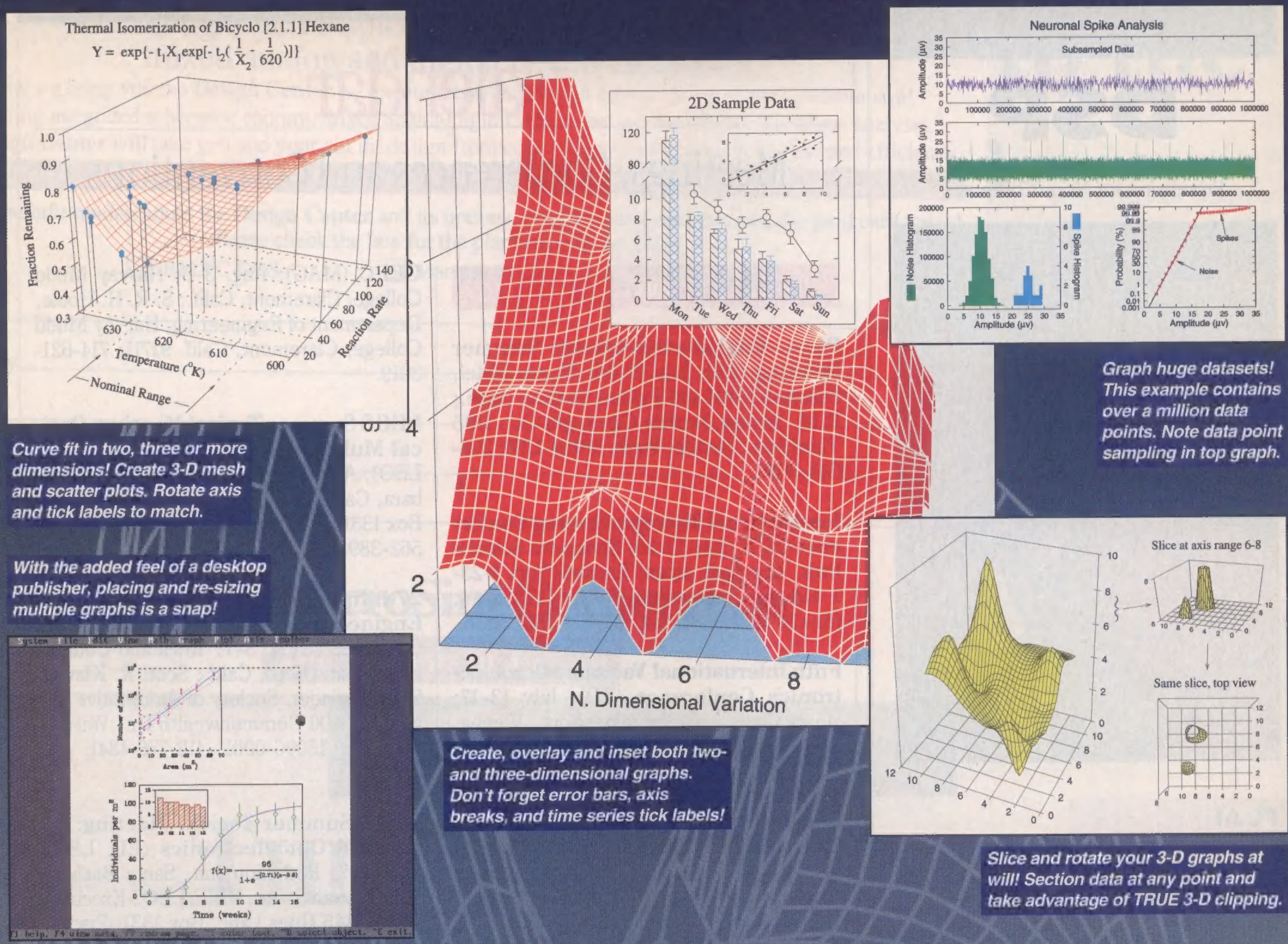
The photograph for "Seeing in the dark" [May, p. 4] was supposedly "taken in total darkness" using an infrared camera. The cars, however, all have shadows underneath them on the pavement. Was the photograph taken during the day, or is there some other reason for the shadows?

Paul Hodges
Tampa, Fla.

The photograph was indeed taken during the day. But, according to the author, that is more or less irrelevant. The thermal-imaging system's detector does not respond to electromagnetic radiation within the visible spectrum. As he explains it, the dark areas under the vehicles are not shadows in the usual sense, but rather areas that are cooler than their surroundings. If the picture were taken immediately after sunset, it would look very similar because the areas under the vehicles would still be cooler than their surroundings.

If the picture had been taken many hours after sunset, the areas under the vehicles might have been lighter than their surroundings. That could happen, the author explains, because the vehicles would inhibit radiation from the ground beneath them, thus allowing it to stay warm longer than the surrounding areas. —Ed.

(Continued on p. 56)



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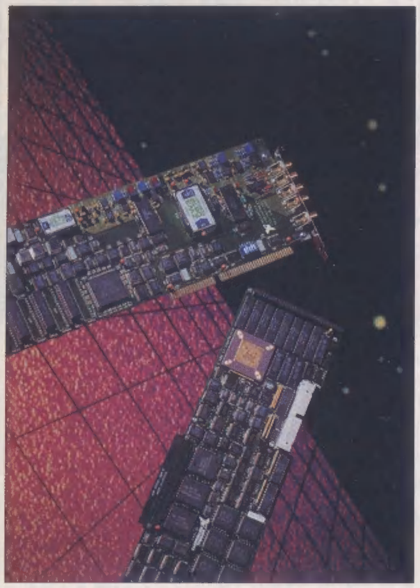

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Calendar

Meetings, Conferences and Conventions

JULY

Power Engineering Society Summer Meeting (PE); July 12–16; Westin Hotel, Sheraton Hotel and Towers, Seattle, Wash.; R.M. Youngs, Seattle City Light Co., 1015 Third Ave., Seattle, Wash. 98104-1198; 206-684-3040.

International Microprocessing Conference (ED); July 13–16; Kanagawa Science Park, Kawasaki, Japan; Tsuyoshi Yuri, 3-23-1 Hongo, Bunkyo-ku, Tokyo 113, Japan; (81+3) 3817 5831; fax, (81+3) 3817 5836.

Fifth International Vacuum Microelectronics Conference (ED); July 13–17; Hotel Chateau Wilhelminenberg, Vienna, Austria; Johannas Mitterauer, Technical University of Vienna, Institut für Allgemeine, Elektrotechnik und Elektronik, Gusshausstrasse 27–29, A-1040 Vienna, Austria; (43+1) 588 01 3682.

Nuclear and Space Radiation Effects Conference (NPS); July 13–17; Hyatt Regency Hotel, New Orleans, La.; James R. Schwank, Sandia National Laboratories, Division 1332, Box 5800, Albuquerque, N.M. 87185; 505-844-2150; fax, 505-846-5004.

Antennas and Propagation Society International Symposium, URSI National Radio Science Meeting, and Nuclear EMP Meeting (AP); July 18–25; Hyatt Regency Hotel, Chicago; Sharad R. Laxpati, Department of EECS (M/C 154), University of Illinois at Chicago, Box 4348, Chicago, Ill. 60680; 312-996-5493.

Magnetic Recording Conference (MAG); July 21–23; Santa Clara University, Calif.; R.L. White, Mathematics and Science Department, Stanford University, Stanford, Calif. 94305-2205; 415-723-4431.

LEOS Summer Topical Meeting: Broadband Analog and Digital Optoelectronics (LEO); July 29–31; Red Lion Inn, Santa Barbara, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 00855-1331; 908-562-3893.

AUGUST

Fifth Biennial Conference on Electromagnetic Field Computation—CEFC (MAG); Aug. 3–5; Harvey Mudd College, Claremont, Calif.; S. R. H. Hoole, Department of Engineering, Harvey Mudd College, Claremont, Calif. 91711; 714-621-8019.

LEOS Summer Topical Meeting: Optical Multiple Access Networks (COM, LEO); Aug. 3–5; Red Lion Inn, Santa Barbara, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

27th Intersociety Energy Conversion Engineering Conference—IECEC '92 (ED, AES); Aug. 3–7; Town and Country Hotel, San Diego, Calif.; Scott R. Klavon, Staff Engineer, Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, Pa. 15096-0001; 412-776-4841, ext. 391.

LEOS Summer Topical Meeting: Integrated Optoelectronics (ED, LEO); Aug. 5–7; Red Lion Inn, Santa Barbara, Calif.; Susan Evans, IEEE/LEOS Executive Office, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3896; fax, 908-562-1571.

Third IEEE Workshop on Computers in Power Electronics (PEL); Aug. 9–11; University of California, Berkeley; Seth Sanders, Department of Electrical Engineering and Computer Science, Cory Hall, University of California, Berkeley, Calif. 94720; 415-642-4425.

35th Midwest Symposium on Circuits and Systems (CAS et al.); Aug. 9–12; Capitol Hilton, Washington, D.C; Lu Klemppinger, Director of Conferences, Division of Continuing Education, 2003 G St., N.W., Washington, D.C. 20052; 202-994-0723.

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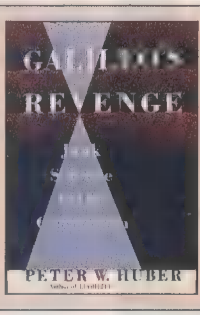
Books

When bad science happens to good people

Jon F. Merz

Galileo's Revenge: Junk Science in the Courtroom.
Huber, Peter W., Basic Books, New York, 1991, 274 pp., $23.00.



This book, the author's second on liability law in the United States, is a scathing critique of the way scientific issues are sometimes handled by U.S. courts. As developed around several cases where the courts have seriously bungled scientific issues, its theme is that the courts' "let it all in" approach to expert testimony—which leaves it to juries to pick between competing opinions—sometimes yields ridiculous results.

Huber argues strongly for more consistent judicial oversight of experts, and limiting their testimony to that "founded on theories, methods, and procedures generally accepted as valid among other scientists in the same field." His call, at bottom, is for the courts to respect the scientific method.

Huber begins this book by directly blaming the proponents of "liability science" for adopting an agnostic attitude to expert testimony. "Liability science," which he attributes to Guido Calibresi of Yale Law School, is the theory that the social costs of accidents can be most efficiently reduced by placing liability on the party that could avoid (or control) accidents at the least cost. Making the "least cost avoider" pay theoretically provides the greatest incentive for the adoption of measures to reduce accidents.

Huber blames "liability scientists" for the emasculation of the Fry rule, named for a case that held experts to the standard summarized above (demanding that testimony reflect generally accepted theories, methods, and procedures). The death knell for this kind of standard was the adoption of the Federal Rules of Evidence in the early 1970s, the author asserts.

In blaming liability scientists for junk science, Huber is not convincing. Over the last 100 years, as Huber himself notes, many cases have been decided in which the courts entertained junk science, which Huber defines as "a hodgepodge of biased data, spurious inference, and logical legerdemain." Likewise, a good number of courts today do get the science right, and Huber mentions some of these, also.

In my opinion, if there has been a recent surge of junk science in courtrooms, it may be due to an unprecedented increase in our technological capabilities. The environmental sciences, for example, allow us to measure minuscule levels of toxins in our environment and microscopic physiological effects of exposures. The medical and epidemiological sciences are making progress in tracing the causes of diseases and treating some cancers and potentially even genetic abnormalities.

Concurrently, our society has become extremely risk-averse. Given the liability ex-

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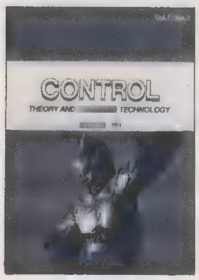

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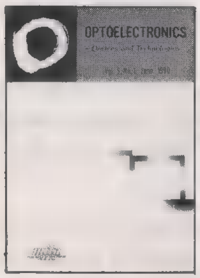

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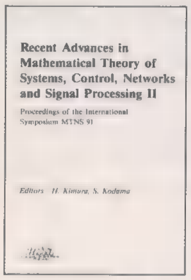

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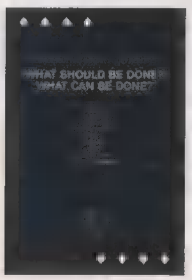

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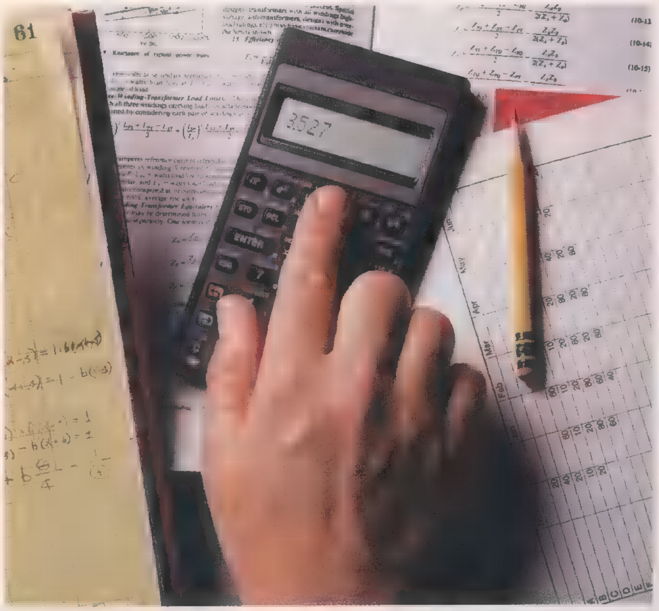

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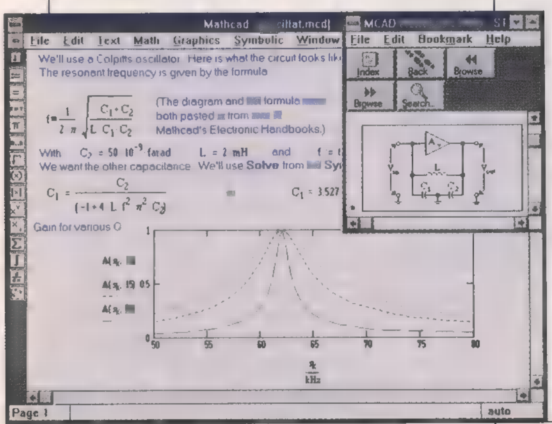

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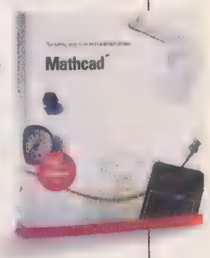

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plosion itself (which may in fact be attributable to the liability scientists), a greater absolute number of junk science cases should be observed. What Huber has not provided is evidence of an increase in the *relative* rate at which these cases are being heard by the courts. Nonetheless, the problem he describes is real.

In the second part of the book, he anecdotally reviews cases where the causal link between an individual's injury and the products or actions of another had been ''proved'' in court by practitioners of junk science. Physicians and others have been allowed to give opinions in court that have been unsubstantiated by scientific inquiry and, even worse, have been inconsistent with the consensus and published scientific views of authorities.

The problem, according to the author, is that the rigors of science, monitored by peer review, are far too seldom required of experts by the courts, a situation that in effect promotes ''malpractice'' and even fraud in the witness stand. The purveyors of junk science in court often base their testimony on pseudoscientific pulp that would not survive even the mildest peer review.

In the third part of the book, Huber ties the anecdotes together, drawing several conclusions. First, the influence of the courts on the market for different products and services, far from reducing the costs of accidents, has very likely led to more disability and death in the United States. For example, despite allegations of unintended acceleration, the Audi 5000 was in fact a safer automobile than others available to consumers.

Furthermore, fetal monitoring and the increased use of Caesarean section have not reduced the incidence of cerebral palsy; the removal of Bendectin and various vaccines from the market has probably done more harm, in terms of injuries from the diseases they treated, than would have been inflicted by the medications' side effects; and intrauterine devices (IUDs)—other than the infamous Dalkon shield—are safer contraceptive alternatives for some women.

Second, Huber asserts that junk scientists within the litigation system have never beaten practitioners of real science to the identification of *bona fide* problems. The fact that scientific consensus may exist outside the courtroom will not stop some courts from trying the issues anew in each case, because the possibility of a favorable verdict supports exploratory litigation by attorneys and junk scientists alike. Both profit from the uncertainty in the system, and their profits in turn propagate more litigation.

Finally, Huber concludes that publication or other peer review of an expert's work should be the benchmark of scientific acceptability, and this is the standard that should be enforced by the courts. Peer review is, after all, quality assurance of the methods used in scientific inquiry. The courts and juries rarely have sufficient training and knowledge to assess the scientific integrity of research, so they should rely on either court-appointed experts or external peer review, he believes. Scientific societies also have a role in establishing ethical standards that require publication of any research performed or presented in support of litigation.

Huber notes that basing law on objective facts reduces uncertainty in the application of the law, making the law more predictable. Predictability, however, is anathema to the plaintiff's bar, because when the law is more straightforward, it is also easier to comply with. Predictability also makes litigation less likely and trials less necessary because the bounds of liability are better known by all parties. To the extent that some courts are willing to bend facts to meet the social goals of spreading costs or compensating for injuries, the public's confidence in the law will be undermined.

The implications of this book are unsettling. First, the courts present junk science with the same solemnity as they do real science. The risk is that jurors may set aside their disbelief amid the formalities of trial, making it too likely that a plaintiff may get a windfall.

Second, the uncertainty associated with the way courts sometimes handle scientific issues makes it difficult to comply with the law and minimize any future risk of exposure to litigation. As a matter of policy, a pharmaceutical company (and the Food and Drug Administration) should rely on good science for evidence of the efficacy and possible side effects of drugs, and should clearly be protected from later claims of quasi-scientists that they did not go far enough in their inquiry. The case of the sleeping pill, Halcion, comes to mind. Of course, the uncertainty is compounded when the scientific community is truly divided over an issue, as it is in the case of the possible cancerous effects of electromagnetic fields.

Third, liability doomsayers may extrapolate from the discussion in this book to future cases resulting from the Supreme Court's ruling in the Johnson Controls case. That case held that women of child-bearing age cannot be barred from hazardous work environments. Inasmuch as about 2–3 percent of babies are born with some defect, one effect of the Court's opinion is to add another defendant—the employer—to lawsuits involving such children born to women who work in hazardous environments.

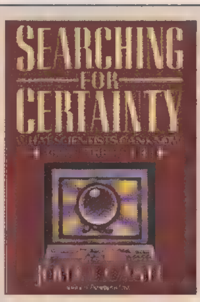
Galileo's Revenge is a worthy addition to the library of those who follow liability issues. By providing some empirical evidence of how the courts are working, the book is an important contribution to the debate about liability. It is well written and engaging, although at times biting in its sarcasm. As an engineer, Huber's frustration with the law is understandable and will undoubtedly be shared by many who read his book.

Jon F. Merz is a postdoctoral research fellow in the department of engineering and public policy at Carnegie Mellon University in Pittsburgh. The holder of a J.D. degree from Duquesne University in Pittsburgh, his interests are in risk analysis and decision-making amid uncertainty.

Certainty and Chocolate Cake

Joseph Fragola

Searching for Certainty: What Scientists Can Know About the Future. *Casti, John L., William Morrow, New York, 1990, 488 pp., $22.95 (hardback; paperback edition to be republished this year by Morrow).*



After announcing a few navigational instructions and rules of the road, the author of this book takes the reader on a wild roller-coaster ride through the spectrum of scientific forecasting, from weather prediction through biology and the stock market to the outbreak of war. In each instance, he slowly guides the reader upward through the scientific bases for prediction in each field, only to drop him or her from each peak by expounding on the limits of the available scientific and mathematical tools.

Casti leads the reader along, challenging the concept of certainty at each turn. He seduces us into agreement in areas where intuition, common sense, and convention support his thesis—who could argue with the fact that long-term weather forecasts are no better than conjecture?—and then surprises us with the uncertainties inherent even in arithmetic, which we have been taught to think of as the epitome of certainty.

He makes us comfortable with the concepts of advanced mathematics by tempting us with a calorie-free version of Sachertorte, the famous Viennese delicacy, generated by an imaginary Chocolate Cake Machine. Little does the reader suspect, however, that Casti is also preparing him or her for the final blow, Gödel's theorem of undecidability.

Beginning with the theorem's ''punchline,'' Casti shatters whatever may remain of our naive notions about scientific certainty by asserting that ''there is an eternally unbridgeable gap between what is true (and can even be seen to be true) within a given logical framework or system and what we

(Continued on p. 19)

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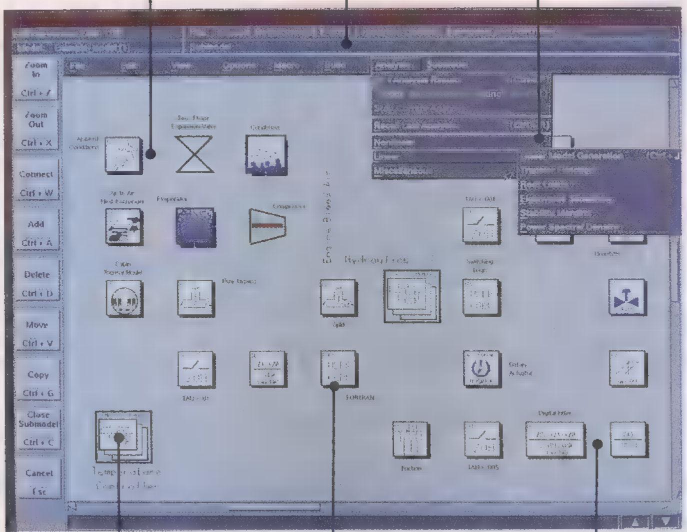

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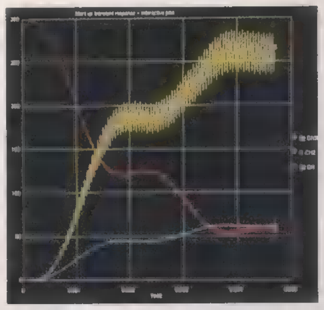

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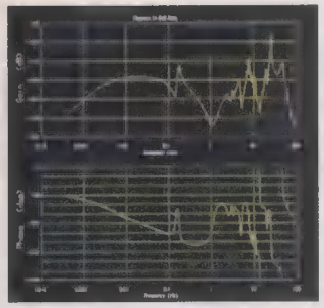

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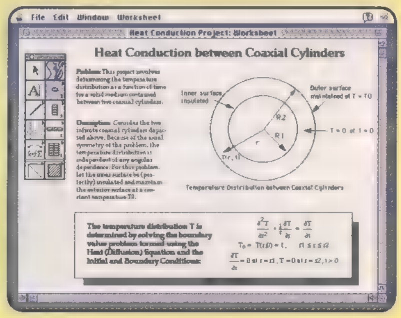

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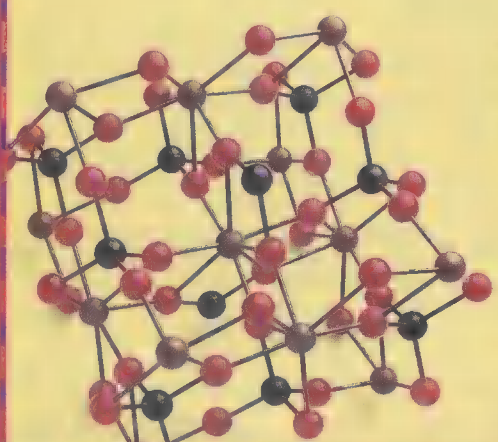

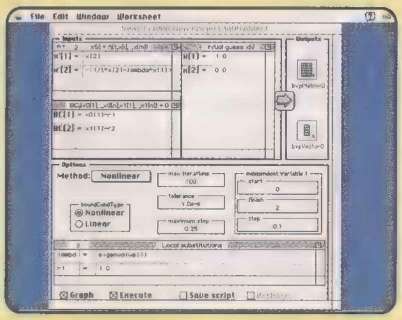

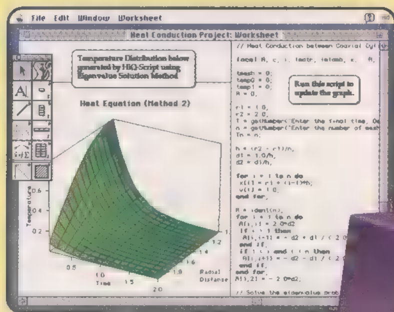

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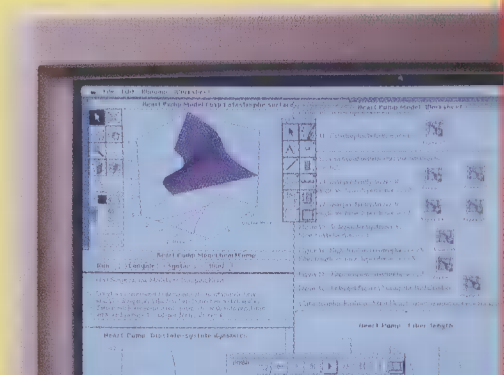

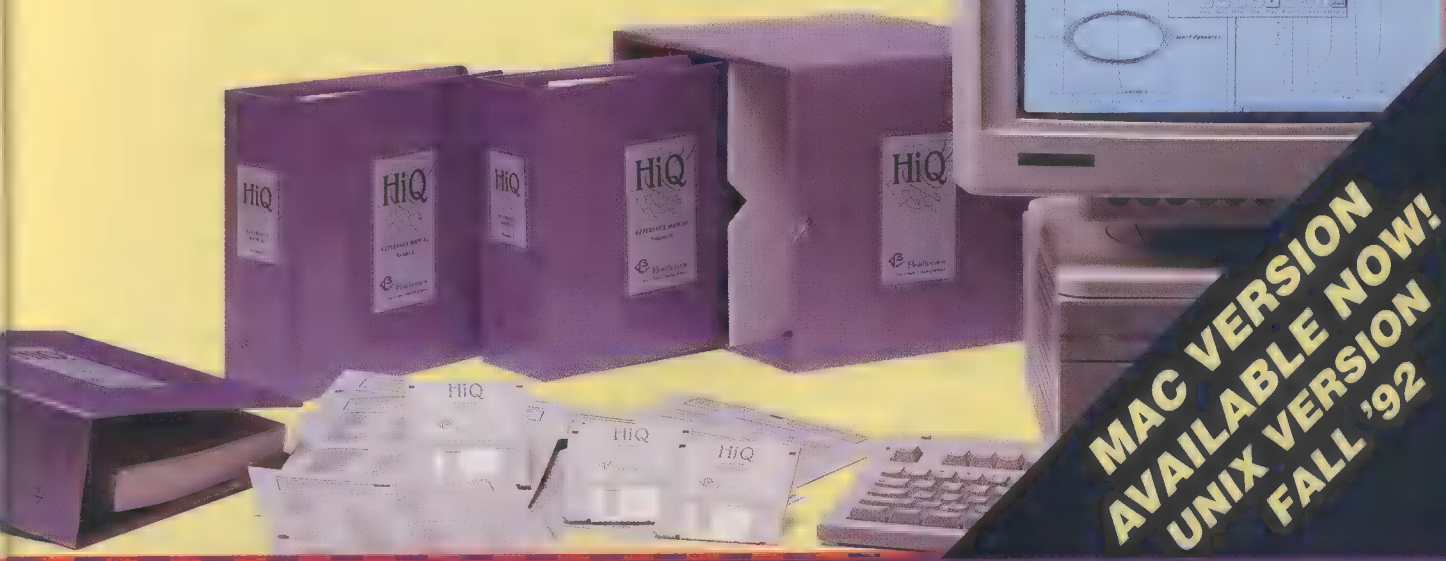

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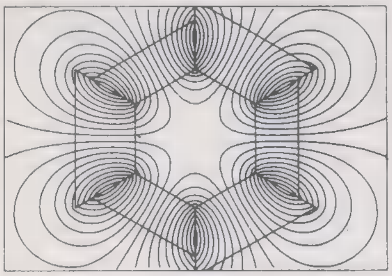

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Calendar

(Continued from p. 8)

Smart Pixels (LEO); Aug. 10–12; Red Lion Inn, Santa Barbara, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893; fax, 908-562-1571.

12th IEEE Nonvolatile Semiconductor Memory Workshop (ED); Aug. 12–14; Hyatt Regency Hotel, Monterey, Calif.; Jim Paterson, Texas Instruments Inc., 13536 N. Central Expressway, MS-944, Dallas, Texas 75243-1108; 214-995-5391; fax, 214-995-1916.

Atomic and Nanoscale Modification of Materials: Fundamentals and Applications (ED); Aug. 16–21; Doubletree Hotel, Ventura, Calif.; Gordon Fisher, Cornell University, 423 Hollister Hall, Ithaca, N.Y. 14853; 607-255-7578.

International Symposium on Electromagnetic Compatibility (EMC); Aug. 18–20; Anaheim Marriott, Anaheim, Calif.; George M. Kunkel, Spira Manufacturing Corp., 12721 Saticoy St. South, North Hollywood, Calif. 91605; 818-764-8222.

Advanced Technology Workshop on Influence of Temperature on Microelectronic Device Failure Mechanisms (RS); Aug. 25; Center of Adult Education, University of Maryland, College Park; Pradeep Lall, Calce Electronics Packaging Research Center, University of Maryland, College Park, Md. 20742; 301-405-5323; fax, 301-314-9477.

International Conference on Solid-State Devices and Materials (EDS); Aug. 26–28; Daiichi Hotel, Tsukuba, Japan; Mitsuo Kawabe, Institute of Materials Science, University of Tsukuba, Ibaraki 305, Japan; (81+298) 53 5066; fax, (81+298) 55 7440.

International Symposium on Applications of Ferroelectrics (UFFC); Aug. 31–Sept. 2; Hyatt Regency Greenville, Greenville, S.C.; Gene Haertling, 206 Olin Hall, Clemson University, Clemson, S.C. 29634-0907; 803-656-0180.

SEPTEMBER

Second Singapore International Conference on Image Processing—ICIP '92 (Region 10); Sept. 7–11; Marina Mandarin Singapore; ICIP '92 Secretariat, IEEE Singapore Section, 200 Jalan Sultan, 11–03 Textile Centre, Singapore 0719; (65) 291 9690; fax, (65) 292 8596.

(Continued on p. 14J)

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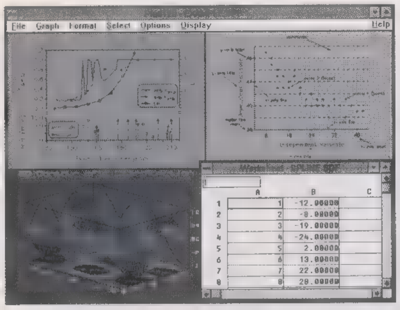

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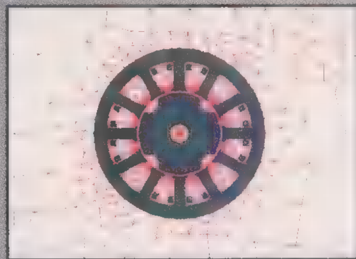

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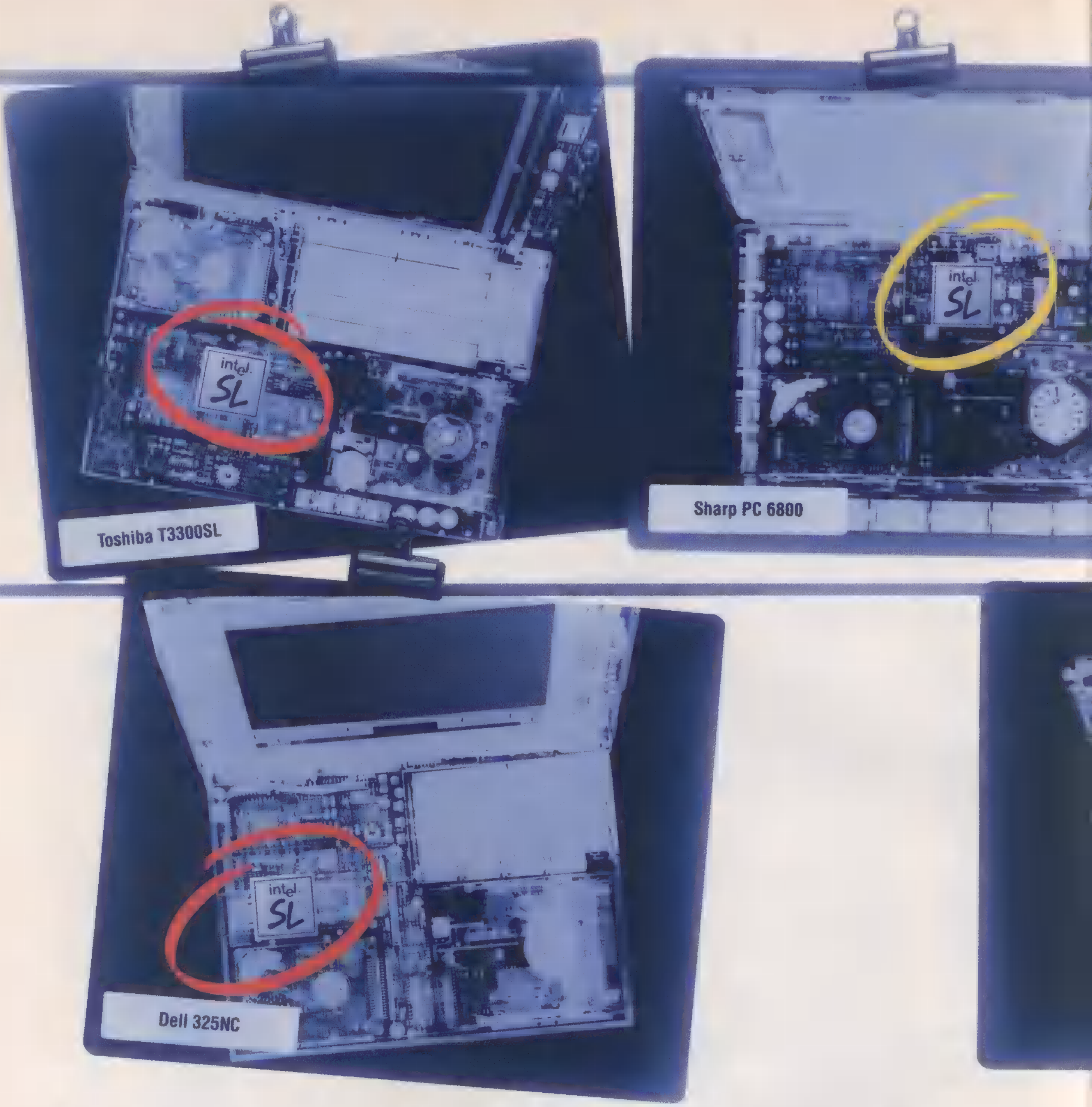

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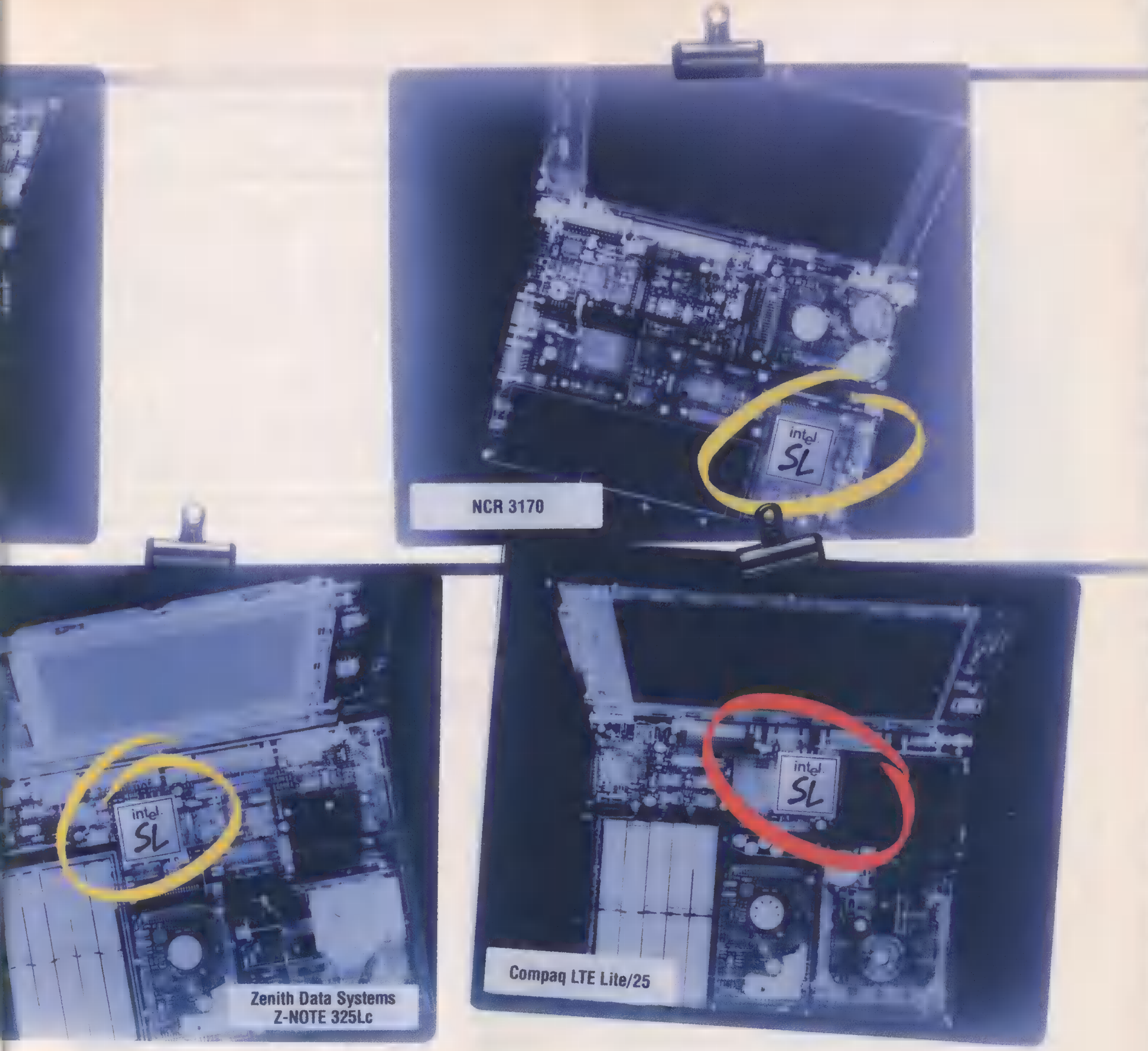

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Symposium on High Performance Distributed Computing (C); Sept. 9–10; Sheraton Hotel, Syracuse, N.Y.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

Fifth Digital Signal Processing Workshop (SP); Sept. 13–16; Starved Rock Lodge, Starved Rock State Park, Ill.; Mark J.T. Smith, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Ga. 30322-0250; 404-894-6291.

International Conference on Control and Applications (CS, Dayton Section); Sept. 13–16; Stouffer Center Plaza Hotel, Dayton, Ohio; Daniel W. Repperger, Armstrong Laboratory, Wright Patterson AFB, Dayton, Ohio 45433-6573; 513-255-5742.

Electrical Overstress/Electrostatic Discharge Symposium (CHMT); Sept. 15–18; Loew's Anatole Hotel, Dallas; EOS/ESD Association, 200 Liberty Plaza, Rome, N.Y. 13440; 315-339-6937.

Conference on Wireless LAN Implementation (C); Sept. 17–18; Dayton Convention Center, Dayton, Ohio; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

Autotestcon '92 (AES, IM, Dayton Section); Sept. 21–24; Dayton Convention Center, Dayton, Ohio; Kenneth Wilkinson, Ateam Corp., 7920 Chambersburg Rd., Dayton, Ohio 45424; 513-237-7971; fax, 513-237-7974.

Application Specific Integrated Circuits Conference and Exhibit (C, Rochester Section); Sept. 21–25; Rochester Riverside Convention Center, Rochester, N.Y.; Lynne M. Engelbrecht, ASIC Seminar Coordinator, 170 Mount Read Blvd., Rochester, N.Y. 14611; 716-328-2310; fax, 716-436-9370.

13th International Semiconductor Laser Conference (LEO); Sept. 21–25; Takamatsu Kokusai Hotel, Takamatsu, Japan; 13th IEEE International Semiconductor Laser Conference, Business Center for Academic Societies Japan, 3-23-1, Hongo, Bunkyo-ku, Tokyo 113, Japan; (81+3) 3817 5831; fax, (81+3) 3817 5836.

International Test Conference 1992 (C); Sept. 22–24; Baltimore Convention Center, Baltimore, Md.; International Test Conference, 514 E. Pleasant Valley Blvd.,

(Continued on p. 58D)

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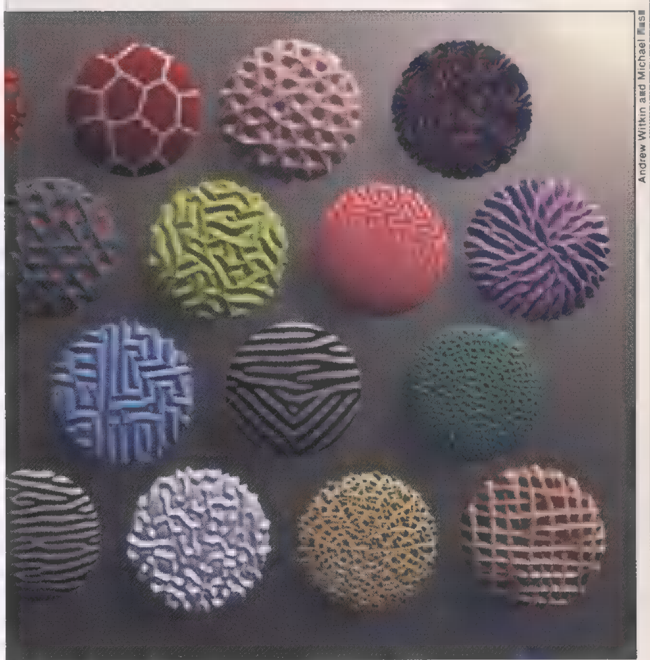

Andrew Witkin and Michael Kass

reated by Andrew Witkin and Michael Kass are examples of the strik- terns and textures they can derive from the biological principle of e top row are reptile, giraffe, coral, and "scalloped" patterns; zebra l and bottom rows. Fanciful patterns include the "purple thing," f the second row; the "space giraffe" on the left side of the bottom econd from right on the bottom.

reactions are over, centrations deter- n the animal's skin

in texture analysis drew Witkin and ith Schlumberger California, turned prints. They found image of a human rcent of the area— the missing piece the principles of re-created image as the original ex- ils. At first glance, as all but indistin- iginal [see photos

iques for generat- s—pebbly, grainy, ined, for example— generally based on . Once the pattern techniques were out distortion onto

Vitkin and Kass saw soon set about de- for synthesizing a much broader and more interesting set of textures than people were previously able to synthesize," said Witkin, now a professor of computer science at Carnegie Mellon University in Pittsburgh.

Although the patterns it produces are complex, the process of reaction-diffusion is described by partial differential equations that are relatively simple. In the equations, different morphogen concentrations at different locations are represented by different arrays of variables. Starting with usually random conditions, the pattern evolves to stability.

The software written by Witkin and Kass solves the equations, and assigns different colors to different concentrations. (Alternatively, for a fingerprint or some other textured pattern, different surface heights can be represented by different concentrations.)

In Witkin's view, the key contributions of his work with Kass are in extending the range of patterns that can be produced with reaction-diffusion—by manipulating the partial differential equations, they have even generated patterns resembling woven cloth—and in producing realistic images of patterns.

The work also adapted the mathematics of reaction-diffusion to the capabilities and

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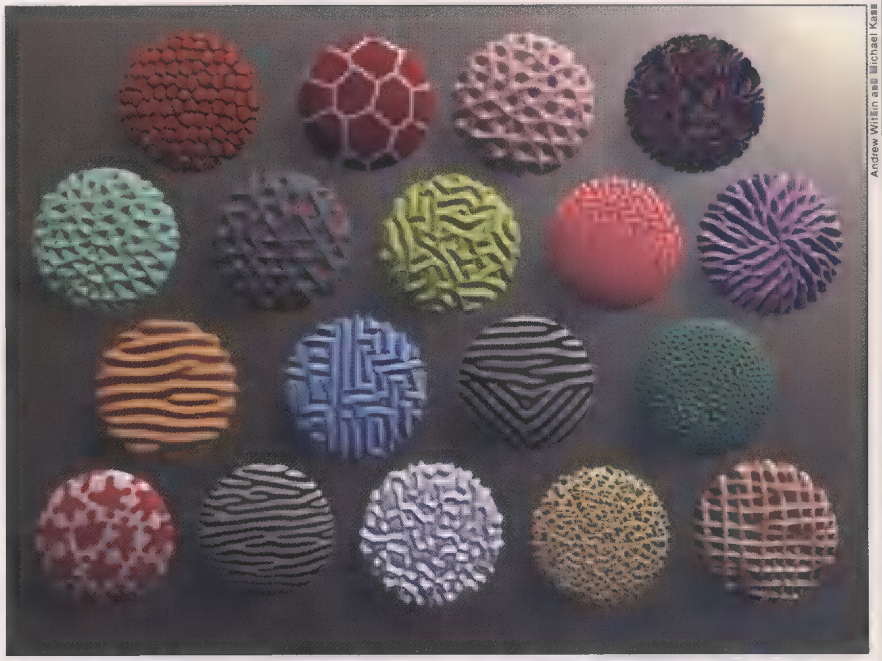
Graphics

A horse of a different color



Andrew Witkin and Michael Kass

These computer images created by Andrew Witkin and Michael Kass are examples of the striking, natural-looking patterns and textures they can derive from the biological principle of reaction-diffusion. In the top row are reptile, giraffe, coral, and "scalloped" patterns; zebra hide appears in the third and bottom rows. Fanciful patterns include the "purple thing," on the right hand side of the second row; the "space giraffe" on the left side of the bottom row; and "beats us," second from right on the bottom.

"Can the Ethiopian change his skin, or the leopard his spots?," asked the prophet Jeremiah in the Bible.

The answer is still no, of course. But recent work in computer graphics shows, in glorious detail, what it would be like if they could. And, far from being limited to men and leopards, the programs can depict the skin of any kind of object or creature—from coral to cobra—and even conjure up hides of imaginary monsters to rival the wildest mediaeval bestiary.

Underlying these graphics programs is the principle of reaction-diffusion, first proposed in 1952 by the British mathematician and computer pioneer Alan Turing. His proposal traced biological pattern formation—a zebra's stripes, a giraffe's spots, or a person's fingerprint, for example—to chemical reaction and diffusion within tissues of the embryo of the animal.

According to the theory, over a period of hours, various biochemicals called morphogens undergo complex reactions, inhibiting or enhancing the morphogens' concentrations. When the reactions are over, the final pattern of concentrations determines the pattern seen on the animal's skin or hide.

While doing research in texture analysis in the mid-1980s, Andrew Witkin and Michael Kass, then with Schlumberger Palo Alto Research in California, turned their attention to fingerprints. They found that a small piece of an image of a human fingerprint—about 7 percent of the area—could be removed and the missing piece "grown" back using the principles of reaction-diffusion. The re-created image had the same pattern as the original except for certain fine details. At first glance, the "regrown" piece was all but indistinguishable from the original [see photos at left].

At the time, the techniques for generating textures and patterns—pebbly, grainy, marble-like, or wood-grained, for example—were few in number, and generally based on random-noise principles. Once the pattern was generated, mapping techniques were used to "paste" it without distortion onto a surface of any shape.

In reaction-diffusion, Witkin and Kass saw a better way, and they soon set about developing "techniques for synthesizing a much broader and more interesting set of textures than people were previously able to synthesize," said Witkin, now a professor of computer science at Carnegie Mellon University in Pittsburgh.

Although the patterns it produces are complex, the process of reaction-diffusion is described by partial differential equations that are relatively simple. In the equations, different morphogen concentrations at different locations are represented by different arrays of variables. Starting with usually random conditions, the pattern evolves to stability.

The software written by Witkin and Kass solves the equations, and assigns different colors to different concentrations. (Alternatively, for a fingerprint or some other textured pattern, different surface heights can be represented by different concentrations.)

In Witkin's view, the key contributions of his work with Kass are in extending the range of patterns that can be produced with reaction-diffusion—by manipulating the partial differential equations, they have even generated patterns resembling woven cloth—and in producing realistic images of patterns.

The work also adapted the mathematics of reaction-diffusion to the capabilities and

Using a computer program based on biological principles, Andrew Witkin and Michael Kass reconstructed the missing piece of an image of a fingerprint. The image, with the piece missing, is shown at the top; the actual portion that was removed is above on the left, while the computer's reconstruction is on the right.

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Circle No. 12

Graphics

limitations of computer graphics. Here, it is not enough to produce dazzling, life-like patterns in two dimensions; like a wondrously elastic wallpaper, they must be capable of perfectly covering objects of any shape. In a sense, the problem is the obverse of the age-old mapmaking challenge of taking the globe and making a flat map out of it.

A tried-and-true method of solving the problem in computer graphics starts with a solid block of texture, and depicts an object as though it had been carved out of the block. The technique is fine for modeling marble, wood grain, or certain brands of soap, but not so useful for depicting, say, an alligator's skin.

For these kinds of surfaces, Witkin and Kass start with a two-dimensional texture or pattern and "stretch" it to cover an object—an alligator's body, for example. Software keeps precise track of every distortion needed to make the pattern fit the object, and these distortions are then written into the equations describing the surface.

"In effect, the pattern is predistorted, so that when we do the stretching needed to fit the pattern on the surface, all the distortion goes away," Witkin explained. Alternative strategies for covering arbitrarily shaped objects with reaction-diffusion textures have been proposed by Gregory Turk, a graduate student at the University of North Carolina at Chapel Hill.

To lend color, lighting, and perspective to their images, Witkin and Kass used photorealistic RenderMan, a commercial graphics program by Pixar in Richmond, Calif.

The validity of Turing's 40-year-old theory has been supported by recent experiments at the University of Bordeaux in France and elsewhere, in which reaction-diffusion was used to create patterns of chemical concentrations similar to biological ones, However, proof that real biological patterns are actually caused by reaction-diffusion remains elusive. In the absence of such proof, Witkin sees computer simulations as a useful adjunct to chemical and biological research in the problem area. "The fact that you can create patterns that strikingly resemble those found in nature is one kind of evidence that that's how those patterns were formed," Witkin said.

Last June, their work in reaction-diffusion texture synthesis won Witkin and Kass the computer graphics prize at the Prix Ars Electronica 92 competition in Linz, Austria. Now in its sixth year, the annual competition is sponsored by ORF, the Austrian Broadcasting Co., and is one of the most prestigious in computer graphics, animation, and music.

COORDINATOR: Glenn Zorpette
CONSULTANT: Andrew Witkin

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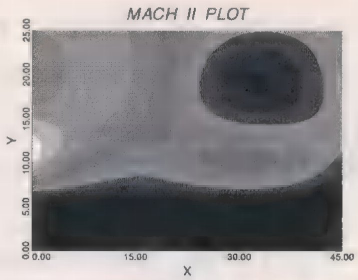

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Circle No. 17

Books

(Continued from p. 14)

can actually prove by logical means using that same system." Having seized our attention with this remarkable revelation, Casti then takes us through the history of early 20th century mathematics, leading up to Gödel's work.

From Alan Turing's Universal Machine, to Thom and Chaitin and their complexity theorem, we begin to understand that "there are fundamental, immovable limitations on our ability to generate truths from rules, i.e., programs." The impact of Gödel's work is then unfolded, and the precise foundation of mathematics established by Bertrand Russell and Alfred North Whitehead in their *Principia Mathematica* is explained. It was the strength of this foundation, we are told, that gave David Hilbert the courage in 1928 to throw down the gauntlet, as it were, by unveiling his Truth Machine to the world of mathematics. Little did he know that in less than three years Gödel would snatch up the gauntlet and use it to pull down the very mathematical foundations the challenge was intended to solidify.

Casti then treats the reader to a carefully laid out exposition of Gödel's proof of his theorem, wisely leaving the formal presentation to those interested enough to avail themselves of his carefully selected bibliography. His explanation includes discussions of such difficult issues as coding systems, the establishment of Gödel sentences, and the mathematical interpretation of the concepts of incompleteness and consistency. In the end, he convinces us that "there is no final verdict in the court of science leading to absolute truth."

If this is true, even in mathematics, where does it leave us? Casti takes the "radical view" that perhaps there is no fundamental difference between the practice of mathematics and that of the natural sciences. In short, mathematics is an empirical activity, and any viable philosophy for its foundations must respect this fact." He concludes with the observation that "in the final analysis the prediction of a mathematical truth ultimately comes down to intuition—the rock bottom basis for every school of mathematical epistemology."

The book does have some flaws: the introductory chapters are a bit long-winded and disconnected, especially the one that addresses biological speciation and forms. But chapters on the stock market and the outbreak of war indicate how vital understanding uncertainty can be to our economic well-being and, indeed, to our survival.

By relating mathematics to empirical science, the book emphasizes the degree to which science can predict or explain everyday events in the natural and human world. This appears to have been the author's intention, and in my opinion he has succeeded commendably. *Searching for Certainty: What Scientists Can Know About the Future* is a "must have" for anyone who enjoyed Douglas Hofstadter's *Gödel, Escher, Bach* and *Metamagical Themas*, James Gleick's *Chaos*, and similar works.

Joseph Fragola (SM), a 22-year veteran in the fields of reliability and risk analysis, is a vice president at Science Applications International Corp. (SAIC) in New York City. He coauthored a book on human reliability analysis and coordinated development of IEEE Standard 500, the Reliability Data Manual.

COORDINATOR: Glenn Zorpette

Recent books

Software Shock: the Danger & the Opportunity. *Pressman, Roger S.*, and *Herron, S. Russell*, Dorset House, New York, 1991, 226 pp., $18.95.

The First 75 Years: A History of the Engineering Foundation. *Metz, Lance E.*, and *Viest, Ivan M.*, Engineering Foundation, New York, 1991, 494 pp., $50.

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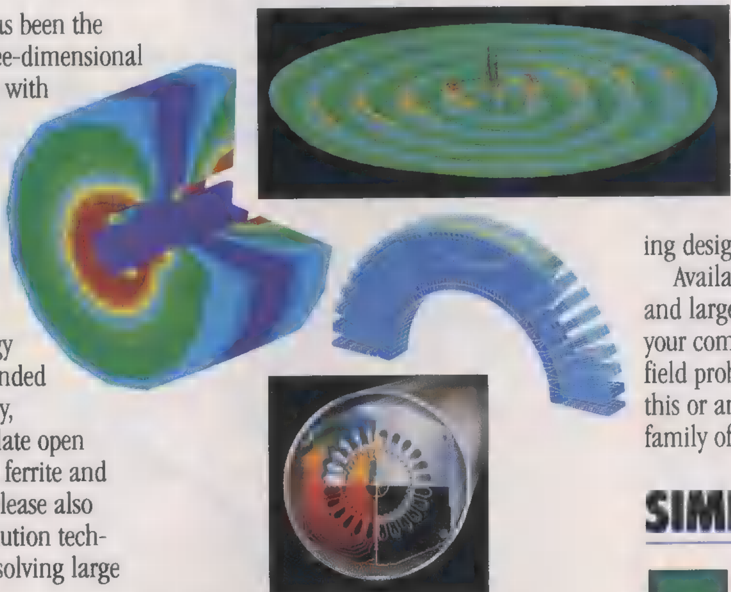

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Circle No. 13

Legal aspects

Photocopying: fair use or unfair abuse?

Joel Miller

As instructor of your company's in-house semiconductor design course, you're relieved you won't have to prepare the course materials: by great luck, you've located an excellent book, perhaps the definitive work in the field. Because it's expensive—US $120 per copy—and since you're not going to cover everything in the book, you have photocopied just a few chapters for the 15 employees who signed up for the course.

Word about the course has spread and you've received over 60 additional requests for course materials. While it seemed fine to make the first set of copies—after all, they're only being distributed in-house for an educational purpose—the situation is getting out of hand. Better check this one out.

WHY WORRY? Modern photocopy technology has made it extremely easy to make copies of journals, books, newsletters, and the like. In many instances, it is faster and cheaper to make photocopies than to buy additional originals. Those advocating this route rationalize that they purchased an original and therefore the author has been fully compensated.

Authors and publishers see this issue from an entirely different angle. Having spent great effort on creating and promoting their works, they take a dim view of reproduction without permission. To them, photocopying is an infringement of the exclusive monopoly inherent in their copyrights and is thus improper. Nevertheless, there are exceptions to this rule, the most pertinent being that of "fair use."

WHAT'S FAIR? Many of those charged with copyright infringement argue that photocopying is permissible under the doctrine of fair use. However, the doctrine of fair use will excuse copying only in very limited circumstances.

Initially developed by courts deciding infringement questions, fair use, or fair dealing as it is sometimes called, has been adopted as part of the copyright laws in many countries. In the United States, fair use was formally codified as Section 107 of the 1976 Copyright Act. (A sister U.S. statute, Section 108, deals with photocopying by libraries, but this aspect will not be discussed here.)

Representative of the fair use doctrines of many countries, Section 107 provides that one may make copies for such purposes as teaching, news reporting, research, and criticism. To determine whether fair use applies, one should consider four factors:

- Whether the copying is for commercial or nonprofit purposes.
- The nature of the material copied.
- The amount and substantiality of what is copied.
- The impact that copying will have on the market for the material.

It is not possible to provide a black-or-white test for fair use. Indeed, in formally adopting the fair use exception, Congress made it clear that "each case...must be decided on its own facts."

FOR WHOSE GAIN? The first element requires one to examine the purpose for making the copies. If the copying is for the benefit of a profit-making venture, it will be harder to establish that photocopying is fair use. In the 1984 "Betamax" case between Sony Corp. and Universal Studios, concerning home videotaping of television programming, the U.S. Supreme Court stated that "every commercial use of copyrighted material is presumptively an unfair exploitation of the monopoly privilege that belongs to the owner of the copyright...."

Determining whether a particular use is commercial requires one to focus not only on the end user but also on the person making the copies. Accused of copyright infringement by several publishers, Kinko's Graphics Corp. claimed that the sale of photocopied excerpts from books to college students was "educational" and thus a fair use.

In her decision last year, however, the judge disagreed with that interpretation: "The use of the Kinko's packets, in the hands of the students, was no doubt educational. However, the use [that is, the photocopying of this material] in the hands of Kinko's employees is commercial."

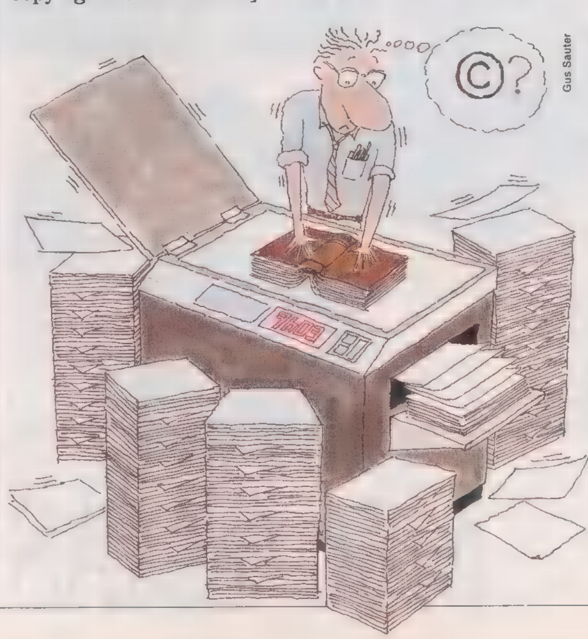
Although it did not involve photocopying, a 1977 copyright case from Japan illustrates a similar consequence of applying the fair use doctrine. Article 30 of the copyright law of Japan permits reproduction of a copyrighted work for personal or home use, but not for commercial purposes. Significantly, this provision specifically excludes copying on high-speed photocopiers, the kind typically used to make multiple copies for commercial purposes.

The parties to the Japanese litigation were bidders in a competition to provide a stage-set for the National Theater in Seoul, Korea. The defendants had copied the plaintiff's drawings and the latter sued for copyright infringement. In response, the defendants claimed that the copying was permitted by Article 30.

Ruling against them, the Japanese court held that the copying of the plaintiff's protected stage-set plan, prepared for a bidding competition in which they were all participating, was not for personal, home, or a similarly limited use but rather for the benefit of the defendants' companies and therefore an infringement.

NOT JUST A NEWSLETTER. Certain works are more broadly protected than others, making it less likely that copying from them will be considered a fair use. For example, Congress has stated that "the scope of the fair use doctrine should be considerably narrower in the case of newsletters than in that of either mass-circulation periodicals or scientific journals," as they are especially vulnerable to mass photocopying.

Earlier this year, a U.S. Federal district court in Texas ordered Enmark Gas Corp. to cease making unauthorized photocopies of *Gas Daily,* an industry newsletter published by Pasha Publications Inc. and sold for an annual subscription of $947. Enmark routinely made "cover-to-cover copies" of the newsletter and faxed additional copies to several of its locations. Although Enmark had indeed paid for a subscription, these activities were not a fair use of the publication.



Nor does out-of-print status excuse copying. Even though the original publication is no longer available, the copyright owner can still hope to collect royalties for copying.

How much is copied from a work has a bearing on whether fair use applies. The amount of copying by Kinko's Graphics for its students ranged from 5 to 28 percent, in many instances entire chapters. That was decidedly too much in the eyes of the court.

I ONLY TOOK A LITTLE. Even where the quantity copied is relatively small, the substantive quality of the material may preclude fair use. In a well-publicized case decided in 1985, the weekly magazine *Nation* printed excerpts from the soon-to-be-published autobiography of former President Gerald Ford without permission. Although the *Nation* had copied only a small percentage of the manuscript, it had excerpted the section dealing with Ford's pardon of his predecessor, Richard Nixon. This material was the "heart of the book," the court decided, precluding a finding of fair use.

If the entire work is reproduced, the decision is easier. Where a newspaper had copied an entire article under the guise of literary criticism, a Canadian court simply declined to find fair use.

The effect of photocopying on the market for an author's work is perhaps the most significant fair use factor. Quite obviously, unrestricted copying could substantially diminish the revenue to authors and copyright owners and thus eliminate much of the incentive for people to write and publish books, articles, and newsletters. Unauthorized photocopying of the *Gas Daily* newsletter by Enmark "rendered unnecessary the purchase of additional subscriptions... and therefore had an obvious detrimental effect...."

Even law firms have been caught in the snare of copyright infringement. Very much aware of the temptation to simply photocopy material rather than pay for additional subscriptions, one enterprising publisher, Washington Business Information Inc., offered a $2000 reward for evidence of illegal photocopying.

The company then learned that its *Product Safety Letter*, a 10-page weekly newsletter costing $657 annually for the first subscription and about half that for additional subscriptions, was allegedly being copied in bulk by the law firm of Collier, Shannon & Scott. So the publisher demanded that the law firm desist and in addition compensate it for the copies made to date. Unable to achieve satisfaction, the publisher brought suit, eventually obtaining a settlement for an undisclosed amount.

BEFORE PUSHING THAT BUTTON. The potential downside to a copyright infringement action should give one pause. In the United States, a copyright owner who wins a suit may elect to recover either actual damages (those losses suffered by the copyright owner) and the infringer's profits, or statutorily specified damages.

Statutory damages are not insignificant: a U.S. court can award as much as $20 000 for each copyrighted work that has been infringed, and as much as $100 000 where the copying is willful.

Also, unlike plaintiffs in many other commercial cases, a successful copyright plaintiff can recover attorneys' fees and court costs. Kinko's Graphics was ordered to pay the plaintiffs $1 365 000 in attorneys' fees and costs, more than twice the amount of the damages awarded!

What should you do about the materials for your in-house course? If in doubt, either obtain the publisher's permission to make the necessary copies or purchase additional books.

Even at the full price of $120 per copy, the cost of the books for a hundred students will be considerably cheaper than the expense of defending a lawsuit.

Joel Miller is an attorney in private practice in West Orange, N.J.

COORDINATOR: Trudy E. Bell

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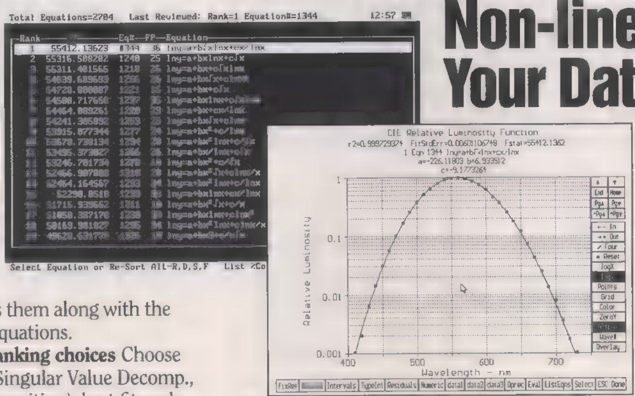

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Circle No. 20

Reflections

Goodbye, Heathkit

The other day a small company in Benton Harbor, Mich., announced that it had closed down one of its lines of business, and would henceforth concentrate on other products. In the business community, this event passed without notice. Had Wall Street reacted, the analysts undoubtedly would have cheered the elimination of an unprofitable division. Smart decision, they would have said, and the stock would have risen.

For us electrical engineers, however, the decision of that little company signified the passing of an era—the end of a time when it was fun and profitable to tinker with electronics. The product that symbolized the electronics hobbyist is no more. It hurts to say it, but say it we must: goodbye, Heathkit. We shall miss you.

Some of my previous articles have touched on the disappearance of electronics as a hobby. From the letters I received afterward, I have sensed that this is a subject that sparks a note of wistful remembrance, at least in the older engineers.

One engineer laments the closing of "Radio Row" in lower Manhattan, where electronics hobbyists could wander from store to store in search of surplus parts, test equipment, and kits of all sorts. That space is now securely anchored to Manhattan bedrock by the tall building-complex known as the World Trade Center. The letter writer suggests that perhaps today a single memory chip would contain more circuits than did all of Radio Row in its prime.

I remember studying the new Heathkit catalogs, weighing my limitless cravings against my available dollars. I remember the thrill of seeing the big boxes with the Heathkit return address waiting for me at home. I remember the great satisfaction in sorting through the little bags of parts, and slowly beginning to create order out of chaos.

Where there was only a tangled jumble of components, like a game of pick-up-sticks, a beautiful television or hi fi would begin to take form and grow. Check mark by check mark, the progress would be recorded in those famous manuals—signposts along a yellow brick road leading in a measured pace toward the ultimate reproduction of the picture in the catalog.

As the kit neared completion, the expectancy would grow, until the final moment of pregnancy and doubt arrived, and all that remained was to turn on the power. The thrill of victory, the agony of defeat—one of them lay just ahead.

Part of the time, I had confidence that the product would work. After all, I was an engineer. Surely there was no problem that could not be bested by my knowledge and experience.

Unfortunately, that was not always the case. Once, having assembled the company's most expensive color television, I could get only a raster display that was broken into shards of color resembling a church window done by a modernist painter. My wife looked worried. I exuded false confidence.

More and more my thoughts were pulled toward Heathkit's motto, "We won't let you fail." But the thought of pleading for mercy and help alongside all the accountants, shopkeepers, and grade school kids who built these kits was demeaning.

The advertisements all said that you did not have to know anything about electronics to build the kits, but I always told myself that surely my engineering training had to count for something. Secretly, of course, I knew that was wrong. The television sets that the grade school kids built probably worked; mine didn't.

Before calling for help, I planned my telephone conversation with the Heathkit experts. There were two strategies. First, I could come across as an expert, who just needed a little professional-to-professional consultation. I could tell them about how I had analyzed all the scope patterns, about my diagnosis of the problem, and so on.

Alternatively, I could pretend to be in the lawn maintenance business or something like that. I could laugh a little, and say some really stupid things, and let them treat me like an overmedicated patient.

Even as I dialed the help-line number, I was undecided as to what strategy would save my television, while leaving my ego intact. When the expert came on the line, I said something incomprehensible about a broken-up picture. "Send us the picture tube," said the expert gruffly. I started to explain about the scope traces, and discovered that I was talking into a dial tone. The new tube did work, although my ego never recovered.

After the big bang of kit creation, I would enjoy a prolonged, warm period of praise and self-congratulation. During this period, I would assume the self-important posture of first-cause rationalization. My wife might comment to some friends about how nice it was to have an engineer-husband who could build these incomprehensible things. I would smile knowingly and say, "I saved money." The pizza delivery person might catch sight of the television and comment that he had never heard of this brand called Heathkit. I would shake my head ambiguously, saying, "I saved money."

Alas, the day finally came when I would stutter, "I saved mon . . . mon . . . mon . . . ." I mean, how could a grown person say, "Well, actually it cost me a lot more than I would have paid for a deluxe Sony, and it isn't as good, but I really like to solder all these little wires together"? I'd probably have to twitch as I said it.

Because of very large-scale integration (VLSI), or because of modern manufacturing technology, building a kit does not make sense anymore. There is nothing inside today's boxes except a few unmarked VLSI chips with 50 gazillion pinouts surface-mounted to a multilayer board. The labels all say, "No user-serviceable parts inside."

It's funny, but I have this vestigial memory that tells me that if I drop a piece of electronics, it will break—as if full of vacuum tubes or something. Actually, it is just a big hunk of silicon.

An engineer wrote to me about building a computer kit in 1977: "That was a major thrill when Basic came up and announced READY on the screen. Last year I purchased a new IBM clone, brought it home, and plugged it in. That was about the same level of excitement as buying a washing machine."

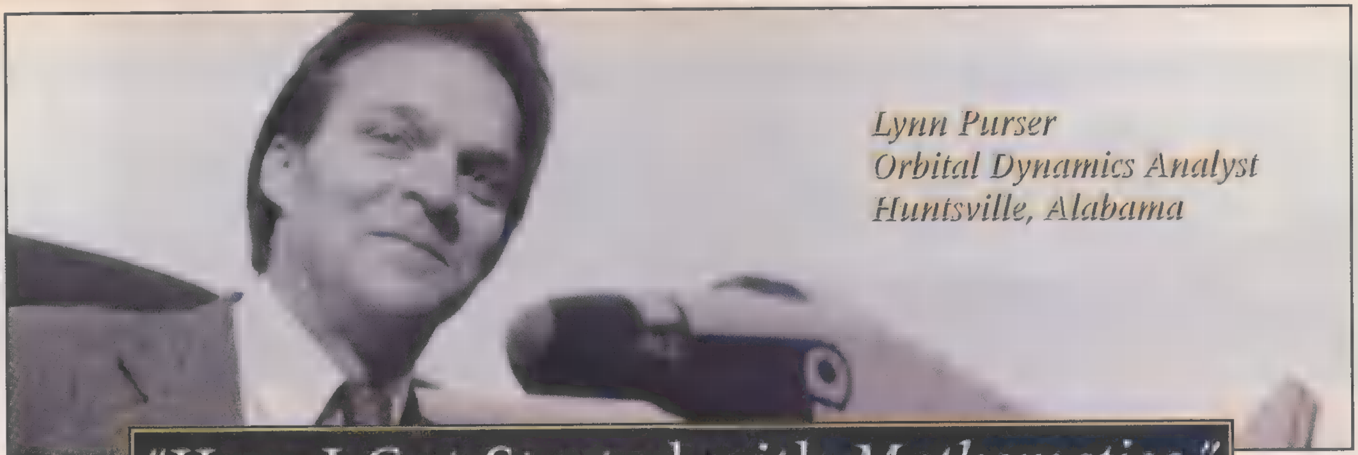
Now when electronics hobbyists get together, one hobbyist asks another, "What kind of computer do you have?" Whereupon the reply is, "I've got a 20-MHz 386; how about you?"

Now the first hobbyist, having trapped the other, smiles condescendingly, and says that he has a 486 machine running Windows at 25 MHz. He then asks about RAM and disk size. This same conversation is repeated endlessly without substantive modification. There is nothing else to talk about.

Of course, the same VLSI that took Heathkit from us gave us the personal computer, and I would not trade my computer for all the Heathkits. So there are compensating advantages for the end of tinkering, including perhaps a new accessibility of the engineering profession to those people who have not grown up as tinkerers.

Still, it must be said: I miss that big box of little parts. I miss the growing check marks in the yellow manuals. Bravo, Heathkit. Thanks for the memories. Thanks for a job well done.

Robert W. Lucky



"How I Got Started with *Mathematica*."

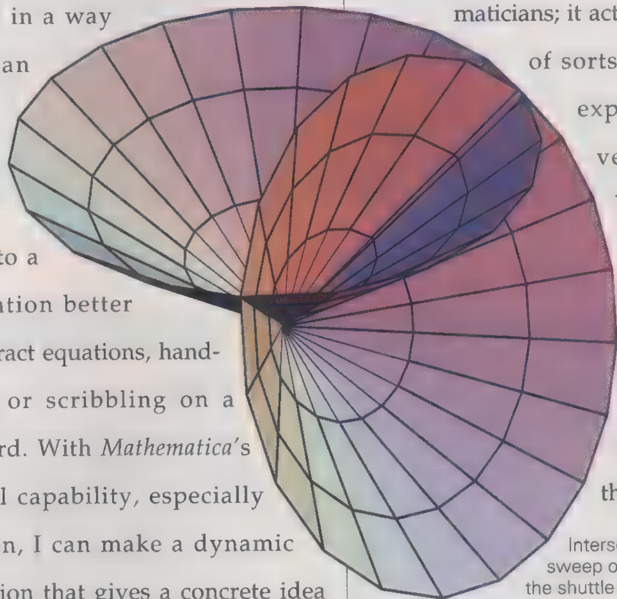
I admit, when I first read about *Mathematica*, I was a little skeptical. I guess mathematicians are like anybody else. Sort of like auto workers being replaced by robots—some mathematicians were skeptical of something that might replace them. So when my firm offered an in-house training seminar on *Mathematica*, I decided to see what all the talk was about.


Photo Courtesy of NASA

That class was fun. I tried to do things beyond what the teacher was covering—the rudimentary stuff about *Mathematica* syntax. I wanted to do animation and play with the graphics. I was taken with the visual dimension of it.

Working on NASA projects, I have to solve problems and present my solutions in a way others can understand. People respond to a visualization better than abstract equations, hand-waving, or scribbling on a blackboard. With *Mathematica*'s graphical capability, especially animation, I can make a dynamic presentation that gives a concrete idea of what I'm talking about.

Then there's the symbolic power. For example, the first project I tackled with *Mathematica* involved a nasty algebraic equation. I solved it on my own and then let *Mathematica* solve it. We both came up with the same answer. But my solution took a few hours and *Mathematica*'s took a few minutes.


Intersection of fields of sweep of two sensors in the shuttle payload bay.

Now I use *Mathematica* regularly. I don't think it will ever replace mathematicians; it acts as an assistant of sorts. It helps you explore and develop concepts, by handling the tedious details. In that way, you're free to concentrate on more important things.

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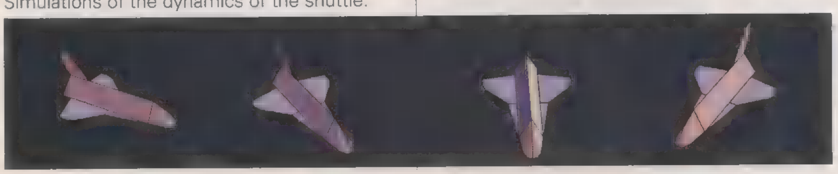
Simulations of the dynamics of the shuttle.



Mathematica® 2.0
The Standard for Technical Computing

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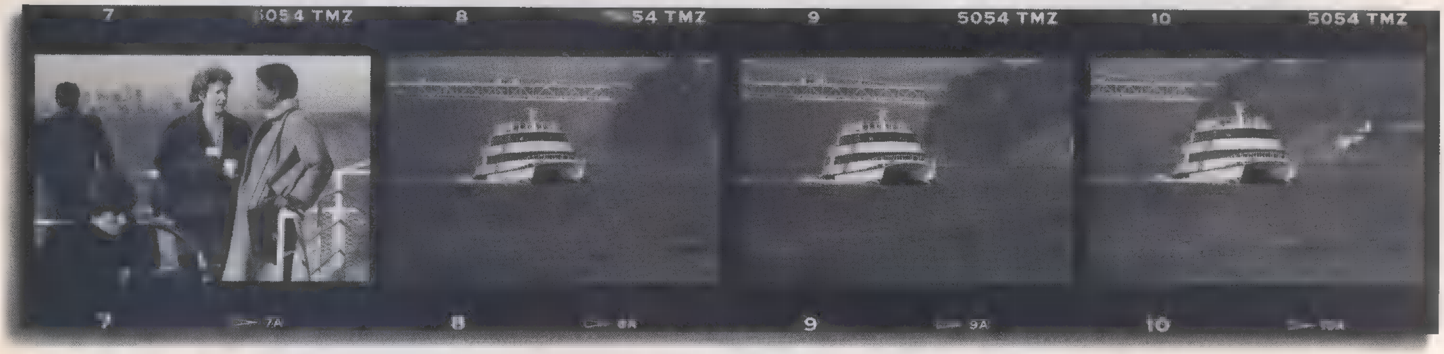
Circle No. 16

"I hear you made a breakthrough in the lab."

"That's right. No one's published on it yet."



"Terrific! You'll be the first."

"Looks that way. I even checked patents."

"This is going to be really big."

"I think so."

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Circle No. 2

Spectral lines

JULY 1992 Volume 29 Number 7

New curricula

For years now electrical and electronics engineers have been grousing about the courses they are required to take as undergraduates. And their employers have been complaining that new graduates are not ready to go to work as *bona fide* engineers.

Outside the United States, the situation is somewhat different. Often the employer does not expect the new graduate to hit the ground running, and is ready to make a further, gradual investment in helping make him/her a good engineer in anticipation of gaining a qualified lifetime employee.

But such is not generally the case in the United States, and there is little chance that this will change. It is ingrained in the culture.

So what are electrical engineering schools in the United States doing about the traditional mismatch between curricula and job expectations? For one thing, educators are listening more to both students and employers. They are finding that while the complaints have not changed much in nature over the years, they have deepened in degree, and for good reason.

Today's incoming students do not have the hands-on hobby experiences that help them sense what engineering may be about. They therefore lack a warm feeling of confidence that the courses they are taking are tools that will later be put to good use. And many have been shortchanged in their K-12 math and physics education.

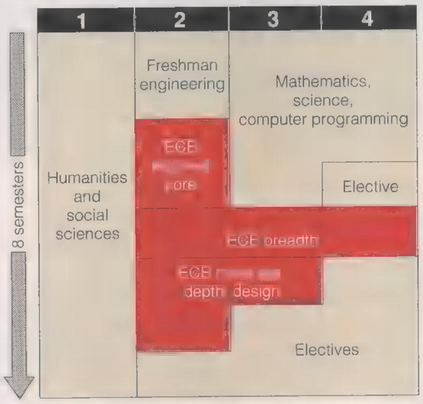
With these handicaps, many students drop out of electrical engineering in the freshman year. To help hold on to them, educators, both through consortia and at individual schools, are changing their thinking about EE course material. In one major concession, they are examining how the undergraduate sequence can be made more project oriented—linked to the real world, at least conceptually.

One proposal is to have a design project begin in the freshman year and carry through to the senior year. The necessary courses to support such a project would be scheduled so as to be available when needed—an adaptation of the "just in time" concept to education.

To reinforce this ability to begin a project early in the four years, several schools are putting in an introductory course in electrical engineering in the first semester. It will give students a broad taste of the elements of electrical engineering, without the rigorous mathematics they will get later as they pursue the same topics in greater detail.

A greater emphasis on projects should help overcome the customary criticism by graduates' first employers: new graduates can't address systems problems that involve interdisciplinary interfaces, interpersonal communications, and economic factors.

At Worcester Polytechnic Institute (WPI) in Massachusetts, a committee charged with revamping the undergraduate EE program calls the new approach a "spiral curriculum." Various areas within electrical engineering are revisited so as to promote understanding of the relationships between them while at the same time introducing new analytical tools.



A new electrical and computer engineering curriculum at Carnegie Mellon University features four courses per semester, one of them in humanities and social sciences. In the engineering track, only three courses (all new) are common requirements for all candidates [see text].

Three new courses are deemed critical to the success of the new approach as it is being implemented at Carnegie Mellon University (CMU), Pittsburgh. The first is Introduction to Electrical Engineering and Computer Engineering, required of all freshmen.

In the sophomore year, the student will take two additional new courses plus corequisites. One is Fundamentals of Electrical Engineering, with Linear Algebra as a corequisite. With these, the student covers linear circuits and circuit theory. The other course is Fundamentals of Computer Engineering, with Discrete Math as a corequisite. These cover digital design, microprocessors, and elementary computer organization.

At CMU, a redesign committee found its traditional BSEE and BSCE options in its department of electrical and computer engineering to be no longer optimal, particularly since the two designations tend artificially to separate the two "ends" of the department, when the objective should be to enhance links between EE and CE. In the new CMU curriculum, only a single degree, the B.S. in electrical and computer engineering (BSECE), is offered.

Several coalitions of engineering schools, supported in part by the National Science Foundation, are also concerned with engineering curricula redesign. One of them consists of California Polytechnic State University, Cornell University, Hampton University, Iowa State, Stanford University, Southern University, Tuskegee, and the University of California at Berkeley.

That coalition is looking at curricula that are less rigid in sequence, and courses that are not as compartmentalized and narrowly focused. It seeks to introduce design projects early on, and, as in the CMU and WPI concepts, weave math and basic science as well as interdisciplinary courses and humanities into the entire four-year program.

In the old system, students are fed math and physics courses in isolated modules, so that by the time they get a course in which they might apply some of what they once learned, they've forgotten it.

The innovative educators who are taking this initiative appear convinced that the current curricula can be decomposed and the aggregate course content reassembled in a more palatable and instructive format.

The project emphasis ought to work, providing that students have the chance to become individually involved. If projects are performed in teams, the danger is that the more timid will be relegated to the role of onlookers. This could continue the syndrome of traditional laboratory teams, where the less aggressive end up data-takers and the team partners who decide how to hook up the equipment and make the measurements, while burning out a meter or two along the way, profit most.

Some skepticism notwithstanding, the new concepts appear feasible and appropriate. Those of us who went through the "old way" may ultimately feel we missed out.

Donald Christiansen

How DEC developed Alpha

Bringing a new computer architecture into existence was for Digital Equipment Corp. a critical necessity that radically changed the firm

The fastest commercial reduced-instruction-set computer (RISC) chip around today is based on a new, 64-bit architecture called Alpha. Designed and manufactured by Digital Equipment Corp., the chip works at a clock speed of 200 MHz, making it twice as fast as any previously delivered microprocessor. Not only will Alpha boot the Open Software Foundation's latest version of Unix, but it also runs Digital's VMS—a 15-year-old operating system designed for a totally different kind of computer, the popular complex-instruction-set (CISC) VAX minicomputer. Alpha's VMS capability gives VAX users a smooth transition path from CISC to RISC computing.

In April, a prototype system based on a 150-MHz version of the Alpha chip was shown at the DECworld Exposition in Boston. It outran currently available machines from several competitors, including the high-performance model 730 PA-RISC workstation from Hewlett-Packard Co., Palo Alto, Calif. ["How ICs impact workstations," *IEEE Spectrum*, April 1991, pp. 58–65, 68]. While formal benchmarking of the Maynard, Mass., firm's system is not complete, it may well come in at about 110 SPECmarks, versus the 75 SPECmarks of HP's delivered implementation. SPECmarks, an average number based on a computer's ability to run a series of four integer and six floating-point programs, have become the standard for measuring RISC performance.

Lured by this performance, over 600 software suppliers have agreed to port their software to the new architecture. Among them are leading companies in electronic design automation such as Mentor Graphics Corp., Beaverton, Ore., as well as computer-aided-software-engineering (CASE) companies like Cadre Technologies Inc., Providence, R.I. The porting has already begun, despite the unavailability of Alpha-based machines until later this year.

DEC has committed itself heavily to open systems with Alpha, licensing the architecture to other system manufacturers. Cray Research Inc., Eagan, Minn., and Kubota Corp., Osaka, Japan, have already committed to adopting the architecture for future products. A partner willing to manufacture chips is also being sought.

Alpha comes none too soon for Digital; losses have been piling up, and it has had to downsize. The firm's introduction of a dozen aggressively priced VAX machines in late October 1991 did little to keep competitors' fast, relatively inexpensive RISC-based machines from eroding DEC's market share. Of the top three U.S. computer makers, Digital alone lacked its own RISC CPU design; it licensed the RISC chip it used in its workstations from MIPS Computer Systems Inc., Sunnyvale, Calif.

With Alpha, DEC controls its own destiny in the fast-growing workstation market. Alpha's support of OSF/1 Unix and the forthcoming Windows NT from Microsoft Corp., Redmond, Wash., will make the firm a serious contender in that market, while its support of VMS (rechristened Open VMS and now available to other would-be suppliers of Alpha systems) promises to stem the flow of customers from DEC to other vendors.

From their introduction in 1977 to the late '80s, VAX minicomputers were a technical and marketing success. They were the computing hub of many technology-driven companies, sending spokes of RS-232 cables out to a rim of VT100 terminals that kept the science and engineering departments rolling. Popular CASE tools were written to run under VMS and numerous engineering simulations and analyses relied on VAXes. Today, the VAX's ability to perform certain computations (the SPECmark benchmark, for instance) is the basis for quantitative comparison of computer performance.

> Alpha's 25-year life expectancy envisions a 1000-fold performance increase—to 400 billion instructions per second

But toward the end of the '80s, some realized that shared computers would one day give way to powerful, single-user workstations networked to powerful resources. And during that period, the banner of open systems was unfurled by Sun Microsystems Inc., Mountain View, Calif.; users were demanding nonproprietary designs that would slip into their computer operating environments like light bulbs into a socket. For manufacturers of proprietary mainframes and minicomputers, chaos lay ahead.

SUMMERTIME BLUES. In the late summer of 1988, a number of top-level engineers at DEC found themselves idled. Several of these "consultants"—DEC engineers whose accomplishments make them special design resources—had been involved for the past three years in the Prism project, whose goal was to develop DEC's first commercial reduced-instruction-set computer. (Titan, a research project to construct very high speed RISC with emitter-coupled logic, or ECL, began in 1984 at DEC's Western Research Center in Palo Alto, Calif., but was never considered commercial.)

The Prism architecture was to consist of a set of integer and floating-point chips. But, by June 1988, the Prism team did not yet have a launchable 32-bit RISC machine; the integer chip design had not been fabricated and the floating-point unit was still in the early design stage. Further, the associated compiler, code-named Gem, was also in early development.

At a stormy meeting that month, DEC's senior executive committee, which determines major business directions, decided to adopt the RISC architecture from MIPS, rather than to go with Prism. While Prism's design was to prove much faster than MIPS's (in the fall of 1988, it was shown that Prism would run at 60–80 MHz), MIPS was much further along and would allow DEC to gain a foothold in the open systems market within a year.

Dave Cutler, who had headed up the Prism development team, was disappointed over the cancellation and left DEC about a year later (for Microsoft Inc., where he is now in charge of developing the Windows NT operating system). Others who had worked on the project felt likewise.

As that fateful June meeting was coming to a close, Robert Supnik recalled, a senior officer told him, "You know, this RISC technology stuff might pose a real threat to our

Richard Comerford Senior Editor

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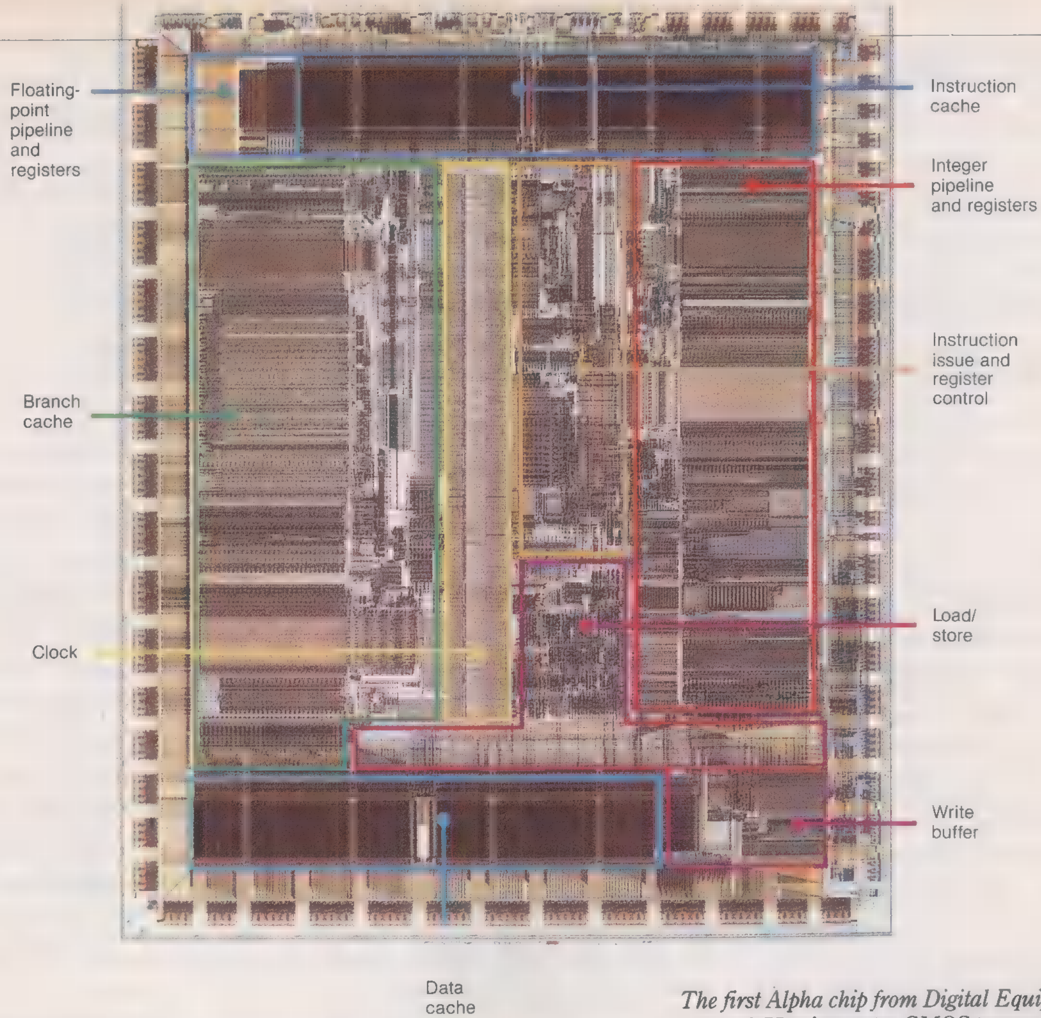
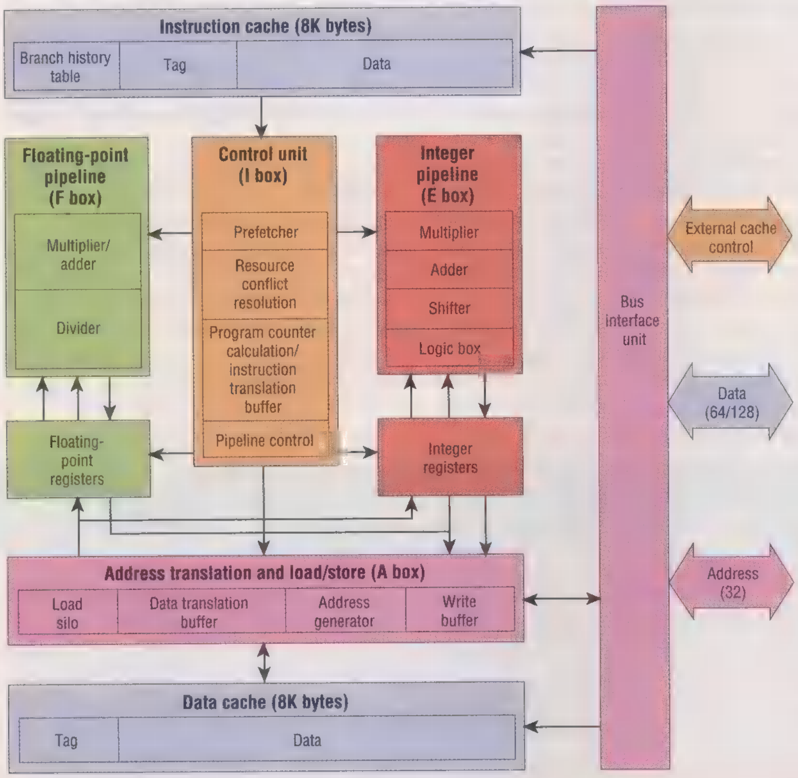




The first Alpha chip from Digital Equipment Corp. uses a 0.75-micrometer CMOS process with a minimum channel length of 0.5 µm. Contained in a 431-pin package, the 16.8-by-13.9-mm die marshals 1.68 million transistors to implement 8-K byte instruction and data caches, floating-point and integer units, control logic, addressing logic and clocking distribution. The clock's single-driver circuitry is centralized to minimize the delay to any point on the chip. Working from a 3.3-V power supply at an internal rate of 200 MHz (for which a 400-MHz external clock is required), the chip consumes 30 W.

The initial implementations of Alpha can handle two 32-bit instructions per cycle; however, instructions for storing an integer and performing a floating-point (FP) operation, or for an FP store and integer operation, cannot be carried out simultaneously. The control circuitry (I box) fetches instructions and distributes them to two of four functional units: the integer unit (E box), the floating-point unit (F box), the load/store unit (A box), and the branch execution (program counter calculation/instruction translation segment of the I box). The architecture is scalable so that future implementations could execute more instructions in parallel.

The bus-interface unit allows the user to configure the external data path for either 64 or 128 bits, adjust for the desired external cache size and access time, employ either emitter-coupled-logic or transistor-transistor-logic voltage levels, and control the clocking rate of the bus interface unit. The choices for these parameters are loaded into the chip's mode registers during power-up.

VMS business sometime in the future. Why don't you go look at this and tell us what we ought to do?'' From this 30-second exchange, Alpha would be born.

In response, Supnik (who was group manager for microprocessor development in the semiconductor engineering group at the time and is now vice president of advanced VAX/VMS systems engineering) formed a task force, originally known as RISCy VAX. Among its first members were Steve Hobbs, a compiler guru; Dick Sites, a specialist in computer architectures; Nancy Kronenberg, a VMS expert; and Bob Stewart, an ECL/systems specialist. Whereas Prism's target had been a new RISC/Unix architecture, the RISCy/VAX goal was to preserve and advance the VAX line. By late summer, the group had begun looking at three hypotheses: the subset VAX, the translated VAX, and the ultrapipelined VAX.

The subset VAX involved dropping all the VAX modes and instructions unamenable to a RISC-like structure, and executing the remaining instructions on a RISC-style pipeline. When an instruction that was not encoded for pipelining came along, the machine would drop back into normal, microcode mode. Dan Dobberpuhl, who eventually headed up the Alpha chip design, remembers getting a call from Kronenberg, who asked, ''Why couldn't we put a few hardware hooks in Prism and port VMS to it?'' Dobberpuhl answered, ''It might be possible; let's talk some more about it.''

For the translated VAX, VAX code would be translated into RISC code by hardware on the fly, stored in cache, and then executed. The problem with this approach was that, with operating system code, the order of instruction execution is not easily predicted, so there would be frequent cache misses and execution would be slow. As its name implies, the ultrapipelined VAX would be a VAX with heavily paralleled execution. Soon it was realized that none of these approaches would provide better performance than other VAX implementations.

HYBRIDS. But because the Prism results were then in hand, ''we knew RISC technology should be able to build a much faster chip for the same technical investment,'' Supnik said. So in September, the group expanded its horizons to look at RISC/VAX hybrids. (Supnik also moved to technical director, a staff position.)

In their investigations, the group checked out what would happen if RISC and VAX architectures co-existed in one system to run VMS at RISC speed. But they concluded the hybrid system would operate asymmetrically, with one side or the other reducing overall system performance.

About this time, Kronenberg and Dobberpuhl suggested building a RISC architecture from scratch with just a few hardware hooks to run VMS. But could an operating system built for CISC hardware work in a RISC environment without slowing down applications?

Kronenberg put the group on track by reminding them that, ''VMS is not VAX—VMS is VMS.'' She pointed out that the VMS operating system has a lot less to do with the VAX architecture than with interrupt schemes and the way in which memory is viewed and accessed—the paging schemes used by VAX systems.

OFF-CHIP OPTION. The big issue was how to move the VAX compatibility question off chip, so that VAX applications could be moved easily to a non-VAX architecture. Hobbs suggested that VAX code could be directly converted to RISC code with binary translators. Sites was skeptical but, after spending a month building a VAX-to-VAX translator as an experiment, he was convinced of the approach's feasibility. ''It was workable,'' he recalled, though, ''unfortunately, it resulted in my wearing two hats, architect and software-translator leader.''

Thus the RISCy VAX team had come up with three concepts radically different from their original ideas. They had decided that DEC could field an industry-leading RISC architecture; the Prism chips had convinced them of that. Second, they realized they could port VMS cleanly to a RISC architecture with some underlying support. (They had looked at moving it to a RISC architecture that was meant to support Unix only, and determined it would add as much as two years to the development schedule.) And third, they learned that applications could be moved to the new architecture at the binary level, using binary translators.

At the end of 1988, the group scattered. Sites, joined by Rich Witek and Dan Dobberpuhl (from the former Prism team), went off to look at the architecture and chip-implementation issues. Nancy Kronenberg returned to the VMS group and began to work on the porting issues.

In February 1989, Supnik took the RISCy VAX proposal to the Strategy Task Force—a group within DEC that determines whether a project is worth pursuing at an R&D level. He recalled that, at the meeting, two questions were first raised. One was, ''If the goal were met of building an industry-leading RISC machine, why wouldn't you run Unix and have just one architecture in the company for both operating systems?'' The other was, ''Should this be a public, open, industry-standard architecture?''

The answers would later make Alpha into an open platform for both VMS and Unix. When the Strategy Task Force gave its approval, however, two project groups were formed: one in semiconductor engineering for the architecture and chip development, and the other in VMS for the port.

For Sites, who had worked in DEC's semiconductor engineering group since 1980, the project was his first opportunity to design an architecture from the ground up, one that would take DEC into the 21st century.

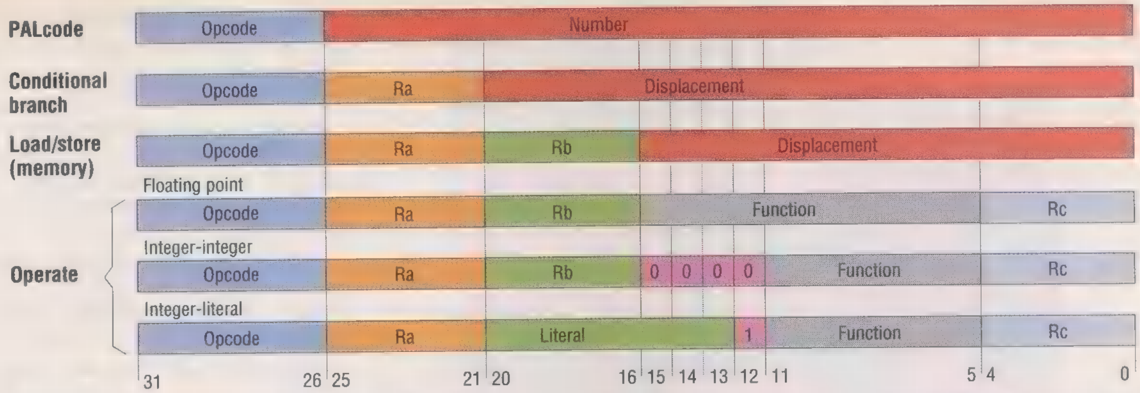
DEFINING THE ARCHITECTURE. Sites's background was ideal. In 1969, he had studied under Fred Brooks, one of the architects of the IBM/360 family of mainframes. Then, in 1972, he worked under RISC pioneer John Cocke [''John Cocke: vision with enthusiasm,'' *IEEE Spectrum*, December 1991, pp. 33–34] at IBM Corp. on a predecessor to the 801 RISC machine, and in 1977 he worked on the first Cray supercomputer. The experiences would mold the architecture that he and co-architect Richard Witek would develop.

Sites and Witek began by looking at two ''threads'' that would run throughout the design. First, to achieve superiority, the design would have to be at least 50 percent faster than its competitors when it came to the market. In February of 1989, the fastest RISC machine was Intel's 40-MHz N10 [''Intel's secret is out,'' *Spectrum*, April 1989, pp. 22–28] and IBM was just introduc-

Ratings of announced reduced-instruction-set computer chips at time of Alpha introduction

Company	Product	Number of components	Internal		MIPS, peak	Mflops, peak
			Architecture, bits	Clock frequency, max., MHz		
Hewlett-Packard Co.	PA-4	2	32	66	132	132
Intel Corp.	i860XP	1	32	50	150	100
IBM Corp.	RIOS	7–9	32	50	200	100
MIPS Computer Systems Inc.	R4000	1	64[a]	100	100	50
Motorola Inc.	88110	1	32	50	150	100
Sun Microsystems Inc./Texas Instruments Inc.	Viking	1	32	50	150	50
Digital Equipment Corp.	Alpha	1	64	200	400	200

a However, MIPS Computer supports only 32-bit operating modes.
MIPS = millions of instructions per second; Mflops = millions of floating-point operations per second.



All Alpha instructions are 32 bits long. The PALcode format [top] lets the machine use an instruction that is not part of Alpha's native set by calling a predefined routine from a library and running it without interruption. For the operate instructions, there are three format variations: floating-point, two-integer, and integer-literal (constant).

ing its RS/6000 line of RISC workstations. By projecting performance increases that could be expected during the new architecture's three-year gestation period, they figured that in 1992 the industry leader would be working at a clock rate of 120 MHz. That meant a minimum clock rate of 180 MHz—a daunting challenge for a CMOS IC design even today.

LONGEVITY. The other thread was to create an inherently long-lived architecture, which would allow systems to grow in performance without a massive changeover in both hardware and software. In many ways, the Alpha architecture would be like a fine Bordeaux: while "drinkable" at its introduction, it would reach its full richness with time.

In thinking about longevity, Sites remembered looking back "over the last couple of decades and asking 'what does it mean?'" He projected that for an architecture to reach the ripe old age of 25, it would have to scale up in performance during that period by a factor of 1000—that is, to 400 billion instructions per second (BIPS).

"Realistically," Sites then asked, "where will that kind of improvement come from?" He surmised that clock speeds could be expected to increase by a factor of 10 before running into fundamental problems of physics. Another order of magnitude improvement could be obtained as the number of instructions issued per clock cycle increased and as compiler design got better at making efficient use of every instruction cycle. But to achieve the last tenfold improvement, Sites reasoned that a system architecture would have to be fully scalable; that is, when the number of processors in a system was increased, system performance would scale up proportionally. Thus the architecture would have to be designed so that, eventually, it could work at clock rates of a gigahertz or more, issue 10 or more instructions per clock cycle, and lend itself to massively parallel processing.

While a high clock rate is basic to high performance, making use of it properly is a multifaceted exercise. For chip design, the key is to lay out an IC so that a fast clock rate is easily maintained throughout the chip. The clocking system takes up a wide swath in the center of the chip. From there, signals can be distributed along electrically equal paths.

The burden of achieving a high clock-rate organization fell on Dobberpuhl, while finding the right material mix for the fabrication processes was the job of Richard Hollingsworth. Before gate-level and IC design could begin in earnest, however, Sites and Witek had to determine which functions would be needed in a RISC machine for the next few decades, and which "artifacts" of RISC's history should be eliminated.

BROADER HORIZONS. From the beginning, the architects planned Alpha as a true 64-bit machine—not a ramped-up 32-bit design. They designed Alpha without a 32-bit compatibility mode like MIPS's R4000—a very conscious commitment to longevity, perhaps at the cost of superior performance with today's 32-bit applications. Although Prism itself was a 32-bit machine, a battle over 32 versus 64 bits that had been fought during that project was won in Alpha. C. Gordon Bell, who was the architect of DEC's PDP and VAX systems (now chief technical officer at Encore Computer Corp., Marlboro, Mass.), had noted in 1974 that bit requirements grew at a rate of 0.6 bit per year. He predicted that, by 1992, 32-bit machines would run out of steam, and Sites and Witek were building for the future.

They also decided that there would be no byte or 16-bit word load/stores. After Sites and Witek had looked at DEC's experience in high-speed machines and quantitative data on the machines' usage of data types, they concluded that handling byte/word operations in the data path would result in much faster systems.

They also banned delayed branch slots from the architecture as a feature that would not scale up. Other implementations use delay slots to cover up latencies associated with program branches, executing following instructions to cover up a two-cycle delay. "That's not consistent with multiple issues of the same operation," Sites said. "With dual issue, it wastes two cycles and the [delay problems] could only get worse."

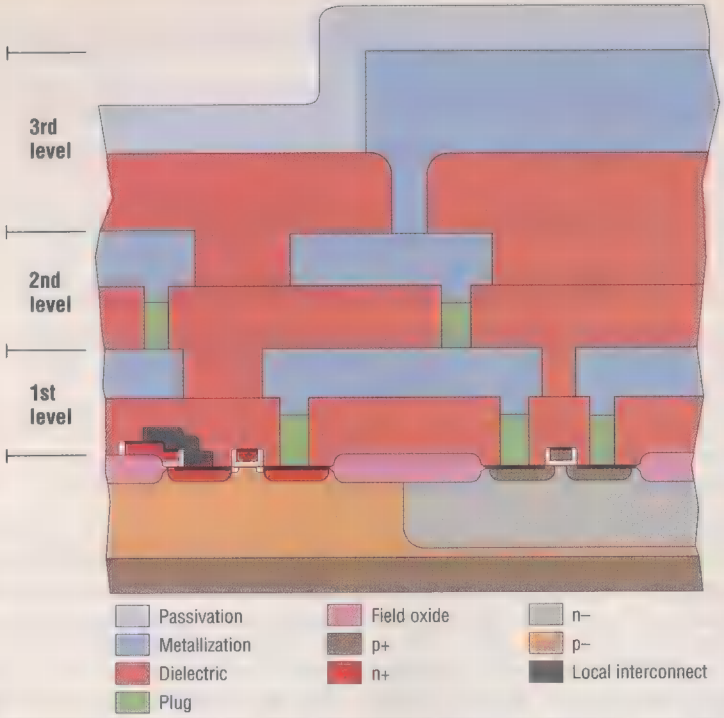
Another artifact they eliminated was the use of precise exceptions. In other RISC and CISC architectures, if an instruction results in an arithmetic overflow or underflow, it causes a precise exception; no instruction following it can be executed, even partially. Such a condition complicates the construction of a heavily pipelined, multiple-instruction–issue machine.

What the architects did was provide for imprecise exceptions. The software designer can let instruction logic continue to issue instructions as long as the operands they require are available. When he or she wants to examine the precise state of the machine when the exception occurred, Alpha's TRAPB (trap barrier) instruction can be used to surround the offending instruction and force an immediate halt.

A LEVEL PLAYING FIELD. Although one of DEC's goals was to prolong the life of VMS-based applications, the Alpha architecture makes few concessions to VAX. One is the inclusion of VAX floating-point instructions; given equal treatment, however, are IEEE floating-point formats. Another is Alpha's ability to support four different modes of memory management, rather than the usual two management modes.

If anything, Sites and Witek did all they could to make sure that Alpha was not biased in favor of any particular operating system or language. For neutrality's sake, Alpha has a fourth basic instruction format. In addition to formats for operate, memory, and branch, a special format called PALcode (PAL stands for Privileged Architecture Library) refers to a group of callable routines for performing instructions unique to a particular operating system.

DEC has defined libraries for VMS and OSF/1, the two operating systems it will initially support. Each has one set of privileged instructions (to be used only by the operating system kernel for system functions) and another of unprivileged instructions (of use in any operating mode, from kernel to user). The instructions call subroutines stored in the libraries that must run without interruption. Libraries can be created for any future operating system; a new one is in the works for Windows NT.



Densely populated Alpha chips use three metalization layers for interconnection; the lower dielectrics must be relatively thick (1 μm) to isolate the fast-switching transistors. Metal will not flow reliably into the narrow (0.75 μm) contact openings in the lower two layers, so a tungsten-filled contact, or plug, is first created using chemical vapor deposition.

Sites remembered that he and Witek spent "the first six months of the project getting rid of artifacts" to make the architecture straightforward and scalable. A measure of their success is the recognition among their peers, such as Patrick Bosshart of Texas Instruments Inc., Dallas, that Alpha is a very "clean" architecture. "It doesn't have a lot of warts and stuff," Bosshart observes, referring to hardware that others have added to RISC to handle unique situations, but that interferes with scalability.

INTO SILICON. While Sites and Witek were working on the architecture, Dobberpuhl, Hollingsworth, and the chip design team at DEC's facility in Hudson, Mass., started thinking about the chip implementation for what, at this point, was known as EVAX, the E being short for Extended. Dobberpuhl remembered that the group from the very start was "committed to a single-chip implementation. They felt the advantages of ■ single chip were extremely significant." Thus, unlike Prism, Alpha's floating-point unit and primary cache would be incorporated with the integer unit.

During the spring of '89, the chip design group also developed a plan of attack by talking to the software designers and the system partners—groups within DEC who build complete computer systems and who are, in effect, the semiconductor group's customers. Based on those discussions, Dobberpuhl's crew realized they would have to have prototypes in 18 months to give to the systems and software developers.

But at that time, DEC was using its third-generation CMOS fabrication process, CMOS-3. Since CMOS-3 was ■ 1-μm process, they could not build all the functions needed to meet their high-performance goals onto one chip. What the group needed was CMOS-4, ■ 0.75-μm process then being developed that would not be in a prototype state for 18 months. Besides, it was being driven by another project whose resources no one wished to dilute.

"What we did," Dobberpuhl recalled, "is develop ■ two-tier approach." They would first build a prototype in CMOS-3 that would not include Alpha's full functionality, but would provide a hardware base for prototyping—the kernel of the chip; it would be called EV-3, ■ combination of EVAX and CMOS-3. The EV-3 kernel would then be used in EV-4, the full chip implemented with CMOS-4.

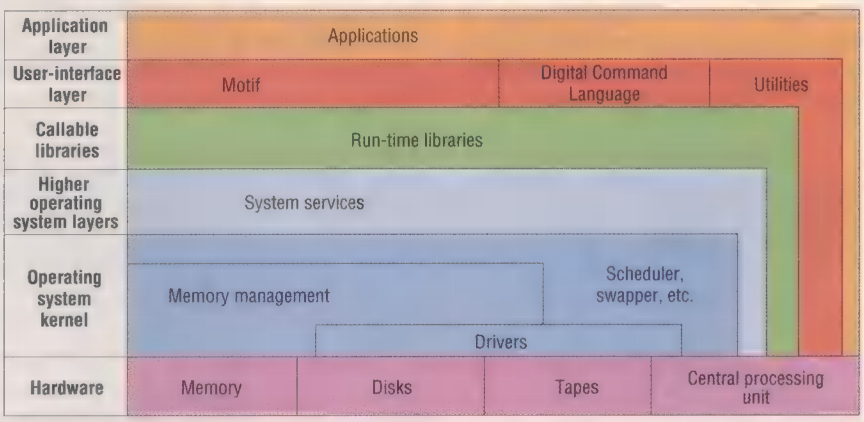
The EV-3 design would start June 1, 1989, and be completed by July 1, 1990. In parallel, they would build ■ prototyping system (which would become known as the Alpha development unit) that would use the EV-3 chip. This would give software designers ■ platform for development and allow the chip designers to validate the design in a system environment.

As no system partners were able to commit the resources needed for the evaluation system project, Dobberpuhl's group did it themselves. In Hudson, Dave Conroy developed the CPU module while Chuck Thacker and Larry Stewart at the Palo Alto Systems Research Center built the backplane, memory module, I/O module, power, and packaging.

"The original plan for EV-3," Dobberpuhl said, "was to make the performance as high as possible to demonstrate the performance potential to the skeptics." The idea of changing DEC's base architecture from VAX to RISC was too radical for many people. So with EV-3, "it was important to capture their imagination." But capturing their imagination by telling them the chip would run at 200 MHz was a double-edged sword. "We also piqued their skepticism; they said, 'Are you guys blowing smoke or what?' "

To achieve that performance and get enough memory for EV-3, the primary cache would have to be off chip. That drove the group to put ECL I/O capability on the chip so they could use biCMOS SRAMs with ECL I/O levels. As it turned out, this was similar to the off-chip cache scheme that HP would use in 1991.

WHAT'S IN A NAME? Alpha was officially approved as ■ commercial project by the executive committee on Halloween 1989 and the second version of the architecture document was distributed for wide review. Around that time DEC's Unix group was becoming interested in the project, so the name EVAX was no longer appropriate. After a long search for a new name, Supnik recalled, "I got fed up. Omega had been



In moving the VMS operating system and related software onto a new reduced-instruction-set computer (RISC) architecture, it was important to realize how little the higher levels of software depended on the basic instruction set of the old VAX hardware. For code that does use the hardware instruction set, binary translators and PALcode were created so as to ease the transition to the new architecture.

used for the recent NVAX project, so I said, 'Fine, the project is going to be called Alpha—end of discussion.' That little thought went into it.''

But the name was not the only thing that changed. For one, it was decided then that the architecture should support not only VAX but also IEEE floating-point formats. The group had been planning to pick up the floating-point design developed for VAX processors and integrate that into EV-3; there was no design available for IEEE floating point and it would be ■ major effort to develop one. ''It was ■ gotcha,'' Dobberpuhl remembered.

Another problem was that they *had* captured the imaginations of their system partners, who wanted to use EV-3 for system development. But if the primary cache was not part of the chip, the partners could not carry over the EV-3 work to EV-4.

Furthermore, Jack Smith, the senior vice president in charge of operations, wanted the development process speeded up by a year, so as to have systems in the field by mid-1992, rather than mid-1993. ''We had some intense meetings to figure it out,'' Dobberpuhl said.

The group finally decided to scrap the external-cache plan for EV-3 and go to an internal cache, so EV-3 would have the same interface ■ EV-4. They would suffer the performance loss in EV-3 chips and not worry about it. To accommodate the cache, they would eliminate on-chip floating-point in EV-3 and just trap and emulate floating-point instructions, because that would be transparent to the software being developed.

So at the beginning of 1990, when the team had thought it was halfway done with EV-3, half the chip had to be changed. The group then went into overdrive through the summer. ''We knew that the schedule was in jeopardy,'' said Dobberpuhl, but the design was released to fabrication in the fall.

FIRST PASS. By December 1990, the first chip was completely functional and ran at 150 MHz. And in January 1991, Ultrix version 4 came up in what Ray Lanza of the Unix group called a ''hole-in-one boot.'' Although Dobberpuhl had a high confidence that it would work (the Hudson facility has had a five-year history of first-pass successes, including the last two generations of VAX CPUs and the Prism chip), he was very relieved when it did come through. ''You never know until it does,'' he observed.

As EV-3 was fabricated and debugged, most of the team worked on the EV-4 design, which had ■ target completion date of June 1991, only nine months after EV-3. ''But this time,'' Dobberpuhl noted, ''they didn't change the rules.'' The group finished the design on time and got their first EV-4 chips late in August.

Working during the Labor Day weekend, they had both operating systems booted within two hours of getting the chips. In fact, they started working with Unix when they noted ■ problem. While some of the team worked on a solution, the rest booted VMS. Then the team went back and booted Unix. All they had done to the hardware was pull EV-3 out of the Alpha development unit and plug in EV-4.

THE OTHER SIDE. While the semiconductor group was busy with the chip, the software teams were working in parallel. For instance, by June 1990, Kronenberg and a group of about five people had created a 300-page VMS design document. A complex task, it involved figuring out what the goals (and non-goals) were, what tasks had to be performed, and how many people would be needed to port about 10 million lines of code in some 7000 modules.

> One of several possible strategies for Digital's future, Alpha was the most radical—and at first, it was not a likely contender

Success was up to Jean Proulx (pronounced ''Prew''). But, she recalled, a real and necessary partnership between the technical people and the managers was lacking. Morale was very low and almost no one thought that the project could be brought in on schedule. An outside consultant advised fundamentally changing how things would be done.

Proulx called the five most influential leaders together, ''and essentially I told them that it was key to Digital that we figure out how to deliver this project on schedule, that the work they were going to do in the next [few] weeks was the most important in their Digital careers.'' After asking the group to figure out how to work on a tight schedule, she left on ■ long-overdue vacation.

FAST TURNAROUND. When she returned, the group had developed an extremely aggressive schedule, ''more aggressive than I could have hoped for,'' Proulx recalled. It included turning around a base level—a group of related functions implemented by the operating system—every six weeks. The project consisted of six major base levels, covering everything from compilers to systems used on a network. Each base level had to be shipped on time to system partners and other groups in DEC who would use it in development. ''At the time, we didn't know how to do it,'' Proulx stated.

Using techniques learned from Ron LaFleur, an independent project-management consultant, they came up with a 14-page schedule that listed every single job each engineer would do. The project manager and the staff would meet every week and identify any area that might be slipping, and then find a remedy. When there was ■ hardware slippage, the group could use the schedule to reassign tasks and push ahead. With this formal discipline, they were able to truly manage software development.

Another part of the program was figuring out beforehand all the decisions that had to be made, who had to participate in those decisions, and who would make the final decision. In addition to the schedule, ■ map of the critical-decision process was made up. This slashed processing time.

The planning paid off when VMS ran for the first time. ''That, to me, was no small miracle,'' Proulx recalled with ■ grin.

NEW WAYS TO MANAGE. Considering all the people ultimately in on the project, the management team that brought it all together was tiny—a program office of no more than 10 people. Supnik, who created the office in the spring of 1989, knew that for Alpha to succeed at DEC, it would have to work within the company's matrixed and decentralized management structure; he was swayed in this by how some very large-scale projects were functioning at the time. ''And the last thing I ever wanted to do was run a large organization with a cast of thousands,'' he said. So the program office was set up to coordinate a growing set of decentralized projects in the many engineering departments within DEC.

Getting resources for the project involved what Supnik called ''internal recruitment.'' In early '80s, DEC's culture was unified under one strategy and one architecture, embodied in VAX/VMS and DECnet. ''And everybody understood it,'' Supnik pointed out. Under the influence of PCs, workstations, Unix, and the like, that strategy broke up around 1988 and many different strategies for DEC's future arose, just as there had been multiple strategies before VAX. Among these possibilities, Alpha was the most radical and not the most likely to win executive approval.

For it to succeed, the people who initially worked on the project had to proselytize the company's technical community. ''And what happened,'' Supnik said, ''was not that people were assigned to the project—they volunteered.'' Within their management structures, the volunteers made the case that a formal budget should be given to the program in the next fiscal year. Ultimately, then, Alpha exists because some at DEC believed strongly enough to sway others.

TO PROBE FURTHER. A general explanation of reduced-instruction-set computers is presented in *Computational Structures* by Stephen A. Ward and Robert H. Halstead, Jr. (MIT Press, Cambridge, Mass., and McGraw-Hill, New York, 1990). Prentice-Hall of Englewood Cliffs, N.J., publishes a series devoted to various RISC processors; among them is *MIPS RISC Architecture* by Gerry Kane and Joe Heinrich (1992), which includes descriptions of the R3000 and R4000 in earlier DEC workstations. ◆

Fuzzy logic flowers in Japan

Born in the United States in the 1960s, the fuzzy logic approach is now catching on for many control and other applications

Fuzzy logic in Japan is becoming a textbook example of how a theory translates into applications. The idea was first broached by Lotfi A. Zadeh, a professor at the University of California at Berkeley, in a 1965 paper on fuzzy sets. Today Japanese manufacturers use fuzzy logic in everything from cameras to industrial process control. At times they even choose fuzzy logic controllers over conventional types, because the fuzzy kind are easier to design and so cheaper to produce.

Zadeh was struck by the fact that people can base decisions on imprecise, nonnumerical information. In 1965, he was implicitly advancing the thesis that this was one reason why people were better at control than machines. Surely, he argued, electromechanical controllers would respond better to imprecise input if their behavior were modeled on spontaneous human reasoning.

In his 1973 landmark paper in the *IEEE Transactions on Systems, Man and Cybernetics*, Zadeh introduced the concept of a linguistic variable, or one whose values are words, and not numbers. Thus, the linguistic variable "size" might have the values "large," "not very large," "small," and so on. In combination with the notion of a fuzzy IF-THEN rule—for example, "if pressure is very high, then volume is very low"—the concept paved the way for applying the theory to real tasks.

One application was fuzzy logic control.

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In a seminal 1975 paper, Ebrahim H. Mamdani and S. Assilian of Queen Mary College, London, demonstrated that a very simple controller based on fuzzy logic could regulate a model steam engine. About the same time the first significant industrial application—F. L. Smidth Corp.'s cement kiln—came on line in Denmark.

By now these efforts have begun to blossom, primarily in Japan, in a variety of commercial and industrial applications. In 1991, Japan captured nearly 80 percent of the world market in fuzzy logic, along with estimated revenues of nearly US $150 million, gains that could approach $350 million in 1992, according to a recent report by Market Intelligence Research Corp., Mountain View, Calif. Furthermore, as of July 1991, 18 projects concerning fuzzy logic research and development were being funded by Japan's equivalent of the National Science Foundation in the United States, the Science and Technology Association, with substantial increases planned for the future.

FUZZY CONTROL. In a conventional proportional, integral, and differential (PID) controller, what is modeled is the system or process being controlled, whereas in a fuzzy logic controller, the focus is the human operator's behavior. In the first case, the system is modeled analytically by a set of differential equations, and their solution tells the PID controller how to adjust the system's control parameters for each type of behavior required. In the fuzzy controller, these adjustments are handled by a fuzzy rule-based expert system, a logical model of the thinking processes a person might go through in the course of manipulating the system. This shift in focus from the process to the person involved changes the entire approach to automatic control problems.

> A fuzzy controller handles adjustments the way a person thinks: it can set temperature low, medium or high

The inference rules in the fuzzy expert system may take the form "if observed variable x is 'positive medium,' then change the control variable y by the amount 'negative medium.'" The model derives the designation "fuzzy" from its use of such terms as "positive medium," "positive large," and "no change," which in turn form a fuzzy subset of the associated measurement domain. For example, a range of temperature measurements may be represented by the fuzzy subset "very low," "low," "medium," "high," and "very high," each of which is described by a membership function [Fig. 1]. As such, the system being controlled is formally viewed as a fuzzy system. This is why, by and large, fuzzy controllers are simpler than classical PID controllers—they tolerate a certain imprecision in dealing with the problem of control.

Each inference rule actually represents a collection of several rules, structured according to what Zadeh called a "compositional rule of inference." For example, take a rule that says that if the error of a controlled variable and the error's rate of change are "positive small," then the controlling variable should be set to "negative medium" [Fig. 2]; this rule might also implicitly represent the rule that says that a "positive large" error and rate of change call for a "negative large" change in control.

The choice of a nonfuzzy (crisp) setting of the controlling variable, given one or more such fuzzy conclusions, is determined by a

Defining terms

Centroid calculation: (for determining the output of a fuzzy inference system) the computation of the center of gravity of a union of areas bound by membership functions and input signal axes.

Defuzzification: a procedure to find the best crisp (numerical) representation of a given fuzzy set.

Fuzzy control system: one based on fuzzy IF-THEN rules for logic and utilizing fuzzy sets for inputs and outputs.

Fuzzy inference system: a collection of fuzzy IF-THEN rules.

Fuzzy logic: logic that uses linguistic hedges ("very," "more or less," "extremely," and so on), fuzzy predicates ("large," "very large," "weak," "medium," and so on), and fuzzy quantifiers ("many," "almost all," "few," and so on).

Fuzzy set: any set that allows its members to have different grades of membership, each expressed by a number in the interval [0,1].

Fuzzy system: a system whose variables range over states that are fuzzy sets.

Membership function: for a fuzzy set, the mapping that associates each member with its grade of membership.

Neural network: a collection of independent processing nodes that communicate with one another in a manner roughly analogous to neurons in the human brain.

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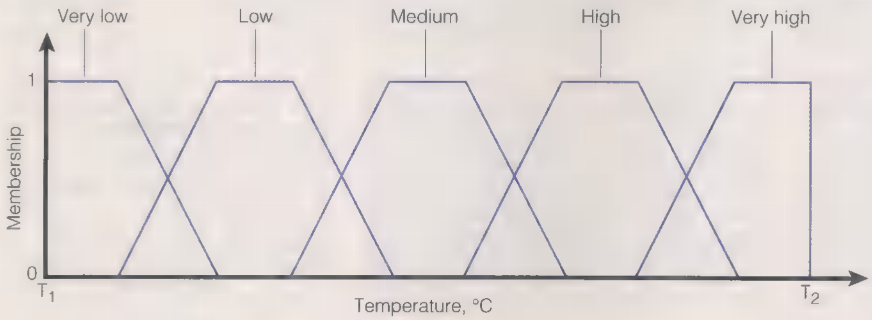
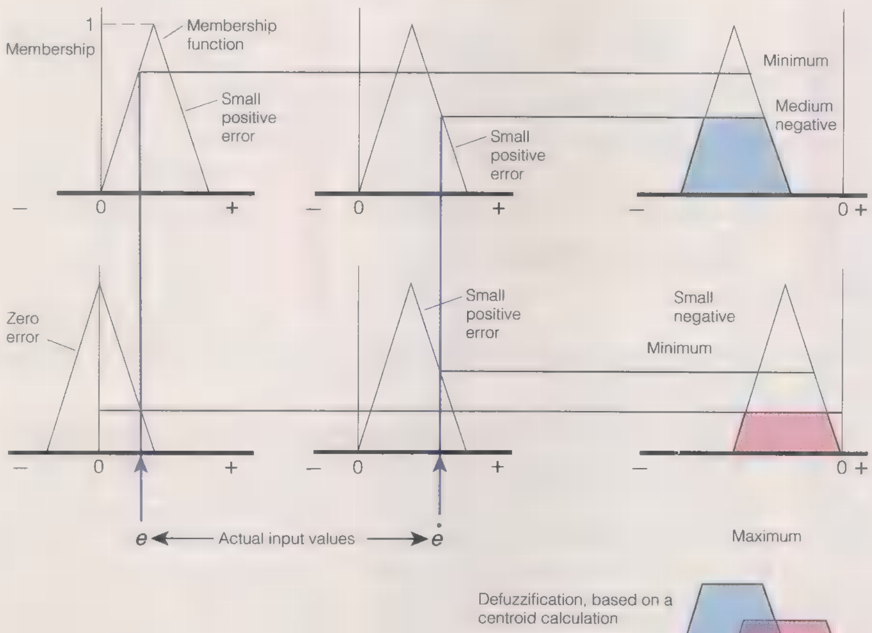
Michio Sugeno

A pilotless voice-controlled helicopter with a rotor 1 meter in diameter developed by Michio Sugeno at the Tokyo Institute of Technology responds to simple voice commands like "hover," "forward," and "up," with each of these functions being fully automated by fuzzy logic control.



[1] Five fuzzy states of a variable, say, temperature T *within a range* (T_1, T_2)*, are elements of a particular fuzzy set. Each state is described by an appropriate word—"low," "medium," and so on. Membership grade functions—curves relating the words to temperature values—have trapezoidal shapes here, as in most current industrial applications, though other shapes are possible.*



[2] The compositional rule of fuzzy inference is illustrated here by two hypothetical inference rules involving three variables: e*, error of a controlled variable;* ė*, rate of change in the error; and* c*, a controlling variable. The first rule is "If* e *is small positive and* ė *is small positive, then* c *is medium negative." The second rule is "If* e *is zero and* ė *is small positive, then* c *is small negative." Usually more rules are needed to achieve effective control [Fig. 3]. Defuzzification follows, here by the centroid method—calculation of the center of gravity of the shaded area—the abscissa of which yields the actual control output value. Other defuzzification schemes (not shown) are also used.*

defuzzification procedure. The most commonly used is the centroid method. Here the fuzzy sets corresponding to all conclusions are combined by a fuzzy set union operation into a final fuzzy set with its associated membership function. Then the centroid of the area bounded by this membership function is computed, and its abscissa taken as the crisp controlling value [Fig. 2].

SOFT LANDING. Credit for the next level of theoretical development and the first commercial implementation of these ideas in Japan goes to Seiji Yasunobu and Soji Miyamoto of Hitachi Corp.'s Systems Development Laboratory in Kawasaki. Fuzzy logic control made its market debut on the new Sendai railway, where it governs all aspects of accelerating, braking, and stopping. Through simulations, Yasunobu and Miyamoto had shown that their controller was superior to the conventional PID controller in several key parameters, including increased accuracy in stopping at the platform, greater rider comfort (smoother acceleration and braking), and lower electric power consumption. They proposed their ideas to Hitachi in 1983, they published their simulation results in 1985, and the Sendai Metro used their control when it opened in 1987. The Sendai project has been so successful that the city of Tokyo has recently decided to apply the same methods to a subway now under construction.

BALANCING ACT. A second event in 1987 combined with the Sendai railway opening to evoke a surge of interest in fuzzy control. At the Second Congress of the International Fuzzy Systems Association (IFSA-87), held in Tokyo, Takeshi Yamakawa demonstrated his inverted pendulum experiment. In this classic control problem, a pole is attached to a vehicle by a hinge such that from an upright position it can fall only to the right or left. The aim is to monitor the pole's angular position and speed and move the vehicle left or right accordingly, so as to keep the pole upright. The shorter and/or lighter the pole, the harder the balancing act.

Whereas Yasunobu and Miyamoto's controller for the Sendai train was implemented in software on a conventional digital computer, Yamakawa designed his own chips: a fuzzy rule chip, which implemented Zadeh's compositional rule of inference, and a defuzzifier chip, which implemented the centroid calculation.

The chips were analog and could run in parallel. The elementary operations employed in the compositional rule of inference, and also utilized in defuzzification, are the arithmetic max and min, which can run much faster on an analog device. The parallelism allowed multiple rules to be fired simultaneously, each on its own chip.

The controller presented at IFSA-87 used seven rule chips and one defuzzifier chip [Fig. 3], and it produced balancing responses nearly 100 times shorter than those of a conventional PID controller.

> The hard part of designing a fuzzy controller is its tuning—teaching it to represent human reasoning

Yamakawa has since gone further and demonstrated nonlinear control with his system. A small platform was attached to the top of the inverted pendulum, and on it was placed a wine glass containing a liquid, or even a live white mouse. The controller nicely compensated for the turbulence of the liquid as well as the totally erratic movements of the mouse.

As for the world's very first fuzzy chip, it was produced in the mid-1970s by Masaki Togai, president of Togai Infralogic Inc., Irvine, Calif. It implemented just the arithmetic max and min operations often used in calculating fuzzy sets. Togai is now very active in the production of fuzzy-based electronics. In addition, Wei Xu, president of Aptronix Inc., San Jose, Calif., has recently developed chips and boards implementing assorted fuzzy inferencing techniques.

CORPORATE INVOLVEMENT. Yamakawa reported his results only after applying for patents on his chips in Japan, the United States, and several European countries. He then traded his patents to several Japanese corporations in return for subsidies for a research laboratory of his own—the Fuzzy Logic Systems Institute in Iizuka, with space for around 40 full-time researchers.

A major contributor to the institute is Omron Corp., Kyoto, which expects about 30 percent of its business (which totals 350 billion yen, or US $2.5 billion, in sales per year) to be fuzzy-related by 1995. This large electronics producer was the first Japanese company to ever obtain a patent for a fuzzy logic controller in the United States, and as of July 1991, claimed over 700 patents worldwide for fuzzy logic devices either acquired, pending, or in application. In addition to very large-scale ICs (VLSI) and boards, these cover a camera that can follow moving objects and a robot sensitive enough to lift cakes of bean curd.

Omron currently employs more than 50 engineers on fuzzy systems R&D, with applications covering tracking problems, tuning, human factors, interpolation, and classification, including handwriting recognition, to mention just a few. As of July 1991, Omron had plans to develop some 40 fuzzy logic devices for use in automobiles, for example, antilock brakes, automatic transmission systems, impact warning and monitoring, windshield washers, light dimmers, and so on.

Plenty of fuzzy consumer products are available in Japan, and a few are now being sold in the United States and Europe. Almost all use fuzzy logic controllers implemented in software on conventional chips. Tokyo's Canon Inc. has applied a fuzzy logic controller in the autofocus mechanism of its new 8-mm movie camera. The Matsushita/Panasonic Palmcorder uses fuzzy logic for image stabilization in a video camera for consumers—the first of its kind. Several major Japanese appliance manufacturers now have their own fuzzy washing machine, which automatically adjusts the washing cycle for load size, type and amount of dirt, and fabric type. Fuzzy control also shows up in vacuum cleaners, air-conditioners, electric fans, and hot plates, plus the automatic transmission in the new Lexus automobile.

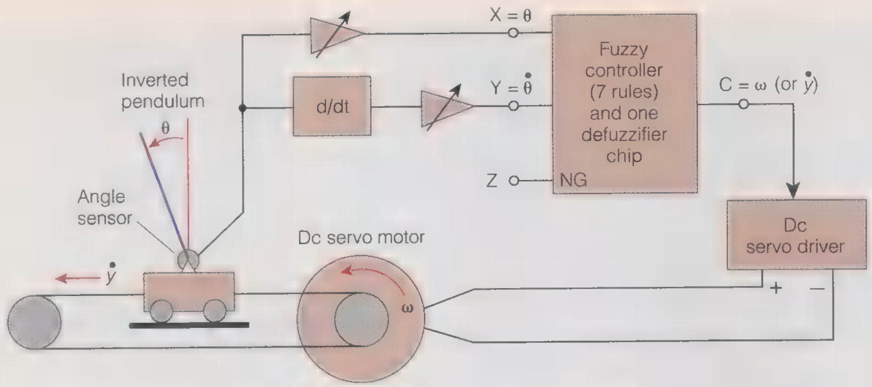
Other manufacturers include Tokyo's OKI Electric Industry Co., which has been marketing fuzzy inference hardware, and recently announced a new fuzzy inference chip.

At Matsushita Electric Industrial Co., Kadoma City, the oft-expressed aim in using fuzzy logic is to make "human friendly" consumer products, and Matsushita is currently the leading manufacturer in this domain. Other producers of fuzzy consumer and/or industrial products include Fuji Photo Film (controlling the flow of powders), Hitachi (control of banks of elevators), Mitsubishi Electric (air conditioning), Nissan Motor (automatic transmission), and Toshiba (ventilation system for expressway tunnels). And this list is far from exhaustive.

RECENT DEVELOPMENTS. An intriguing project is the voice-controlled helicopter being developed by Michio Sugeno at the Tokyo Institute of Technology. Here the objective is to develop a helicopter that obeys voice commands like "hover," "forward," "left," "up," and "land." The control of each axis uses essentially the same fuzzy techniques as ensured vertical stability in Yamakawa'a inverted pendulum.

Hovering is a formidable stability problem—would-be helicopter pilots typically train for weeks before managing to do it manually. Hence automating this operation is in itself an impressive achievement. Sugeno has accomplished all functions for a model with a 1-meter rotor [photo, p. 33], and is working on a 3-meter model. He reported on his current progress at the 1992 IEEE First International Fuzzy Systems Conference in San Diego, Calif., March 8–12.

While the principles of fuzzy control have been understood for some time, no application until recently employed more than a few inference rules. Usually the hardest part of designing fuzzy controller is selecting which fuzzy sets best represent the controlled and controlling variables, namely, the "tuning" of the controller. Most controllers are sensitive to the shapes [for example, the trapezoids in Fig. 1] of these membership functions, and as the number of rules multiplies, trial-and-error tuning



$\dot{\theta}$ \ θ	NL	NM	NS	ZR	PS	PM	PL
PL							
PM							
PS			ZR		PS		
ZR		NM		ZR		PM	
NS			NS		ZR		
NM							
NL							

Source: *Fuzzy Sets and Systems*, Vol. 32, 1989, pp. 177–78 (courtesy of Elsevier Science Publishers and Takeshi Yamakawa)

[3] In Takeshi Yamakawa's inverted pendulum stabilized by a fuzzy controller, θ is angle of pendulum from vertical, ω is angular velocity of the servo motor, ẏ is horizontal velocity of the vehicle. An input for a third (unused) variable is set to NG *(negation) [top]. A table of θ shows seven rules, for example, "if θ is* PM *(positive medium) and θ̇ is* ZR *(about zero), then ẏ is* PM.*" Other states used are NL, NM, PS, and PL ("negative low and medium," "positive small and large," respectively). The experiment shows there is no need for rules that correspond to the blanks in the table.*

methods become less and less feasible.

A recent breakthrough here calls on a neural network, which with the aid of back propagation learns the needed membership functions from a set of training examples. (A neural network interconnects processing nodes in imitation of the neurons in the human brain; the back propagation type carries out supervised learning by feeding output failures to match a desired target pattern back to its input as information to its individual nodes.) Hideyuki Tagaki and Isao Hayashi, researchers with Matsushita's Central Research Laboratory, Osaka, first reported these results at the 1988 International Conference on Fuzzy Logic and Neural Networks, Iizuka, Fukuoka.

Subsequently, Akira Maeda and others of Hitachi's Systems Development Laboratory, Tokyo, have based a tuning system on this idea and applied it in the development of a controller designed previously by trial and error. In just one month they accomplished a tuning task that had formerly taken six. Similar work has been undertaken by, among others, Toshiro Terano of Hosei University, and Masao Mukaidono of Meiji University, both in Tokyo. Nowadays advertisements in Japan for "neuro-fuzzy" products are common, and the two technologies seem likely to continue to evolve in tandem.

Fuzzy control for robots is being pursued by Kaoru Hirota at Hosei University and Shigeki Ishikawa at IBM Japan, in Tokyo. One of Hirota's more dramatic efforts directs a robot to throw darts at an object falling through an array of pegs, as in a pinball machine, so that it scores a hit on just about every try. The robot is a general-purpose, programmable device, and is now being marketed by Mitsubishi. Ishikawa has produced an autonomous robot that uses fuzzy control to avoid stationary and moving obstacles, particularly for seeing their sizes and shapes. Among some more exotic applications are robots for making Japanese flower arrangements, for Chinese character calligraphy, and for inspection of plant seedlings.

OTHER RESEARCH. While the greatest achievements have been in fuzzy logic control, work is in progress in other domains. Tokyo's Hitachi Corp. markets a fuzzy expert system shell, ES/Kernel, which has now sold over 2000 copies. (A shell is a computer program that embodies various knowledge representation and inferencing techniques, and serves as a framework within which to develop specific expert systems.) The Ministry of International Trade and Industry's six-year project, the Laboratory for International Fuzzy Engineering Research (LIFE), continues to pursue fuzzy logic applications in: decision support; robotics, including natural language and image understanding; and fuzzy computing, including fuzzy associative memories. At his Fuzzy Logic Systems Institute, Yamakawa recently unveiled his VLSI "fuzzy neuron" in an experiment in handwritten-character recognition. A fuzzy neuron is analogous to the neuron of hardware implementations of neural networks, except that it takes fuzzy sets as inputs and yields a fuzzy set as output.

At the Hiroshima Institute of Technology, Kazuho Tamano has had preliminary success with an optical fuzzy inference device. Here light is passed through translucent plates on which are inscribed the membership functions of fuzzy sets representing a rule's premises, and the amount of light coming out is measured to derive the rule's conclusion.

Also of interest is Hirota's design for a fuzzy flip-flop circuit, which includes the binary flip-flop as a special case. There has been discussion about initiating a project to develop a fuzzy computer based on Hirota's circuit designs. The machine would embody both fuzzy (multilevel) and classical (binary) information processing in the same machine.

TO PROBE FURTHER. An IEEE video conference entitled "Fuzzy Logic: Applications and Perspectives," featuring Masaki Togai, Lotfi Zadeh, and Piero Bonissone, aired April 25, 1991 (the 41st IEEE video conference, available on tape). The 1992 IEEE First International Fuzzy Systems Conference took place in March in San Diego, Calif. For a conference proceeding (IEEE Pub. No. 92 CH3073-4), contact IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J., 8855-1331; 908-981-0060.

A rich source of information on various aspects of fuzzy set theory and fuzzy logic is *Fuzzy Sets and Applications: Selected Papers by L.A. Zadeh*, ed. R.R. Yager et al. (John Wiley, New York, 1987). A simple and self-contained introduction to fuzzy set theory with a strong coverage of measures of uncertainty and information is *Fuzzy Sets, Uncertainty, and Information* by G.J. Klir and T.A. Folger (Prentice-Hall, Englewood Cliffs, N.J., 1988). An excellent overview of fuzzy control is to be found in the paper "Fuzzy Logic in Control Systems" by C.C. Lee (*IEEE Trans. on Systems, Man and Cybernetics*, SMC, Vol. 20, No. 2, 1990, pp. 404–35).

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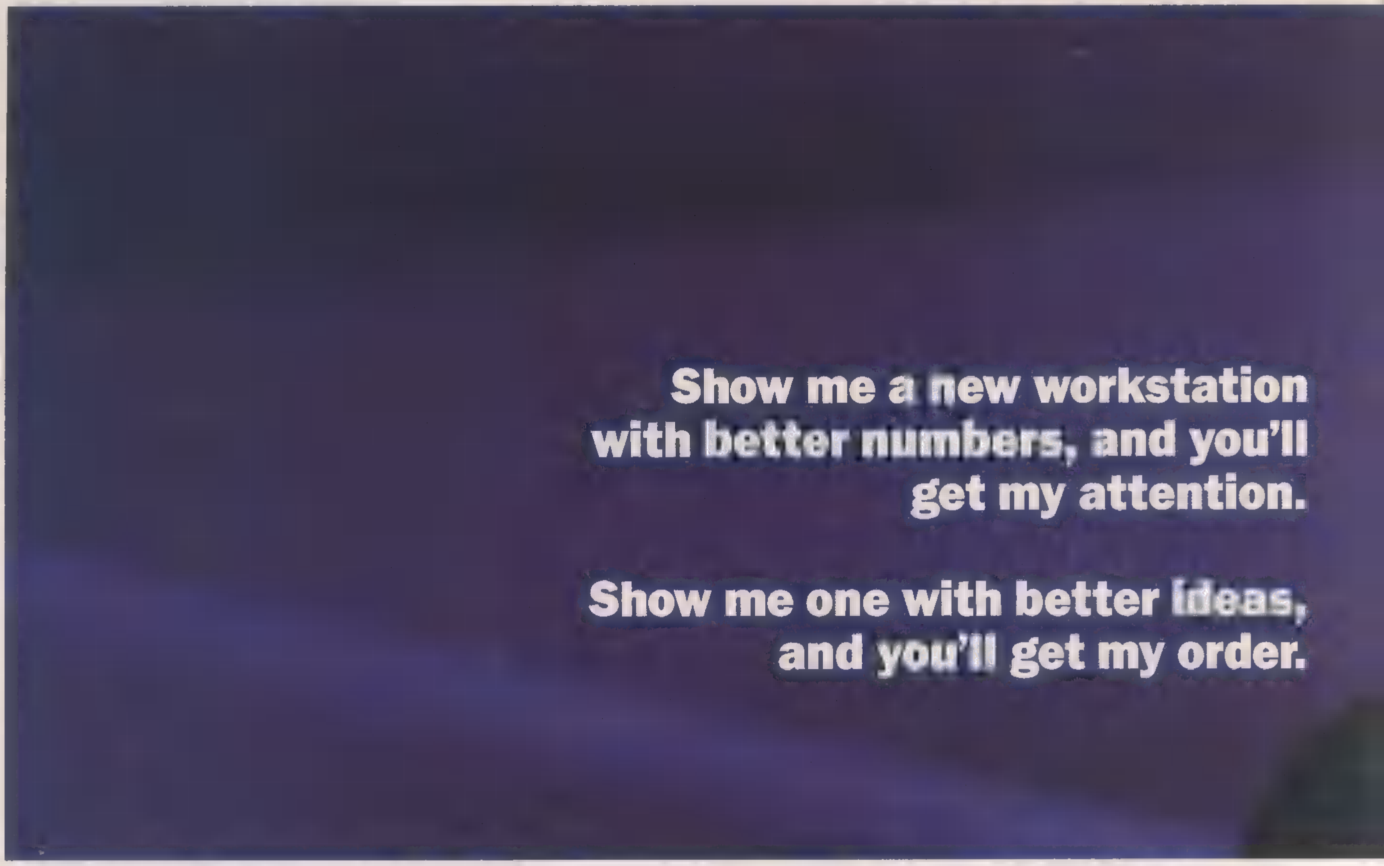

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Circle No. 15

Improving on police radar

Lasers, cameras, and advanced signal processing are poised to help isolate individual offenders on crowded highways

Gilbert and Sullivan were right: a policeman's lot is not a happy one. Take speed enforcement, for example. A cop spots a driver tearing down the road at 120 km/h in a 90-km/h zone. He aims his radar gun at the car to get a legally meaningful reading, and finds that he cannot get one.

The problem: several cars are near enough to the speeder to be included in the radar's beam; as a result, getting a valid reading is impossible. Or the problem might be interference from the ignition of a passing truck. In any event, one more opportunity to prevent injury and death by discouraging speeding has been missed.

To be fair, sometimes the scenario plays out the opposite way, and an innocent person is ticketed when he or she was not actually speeding. But over the years, the main effect of police radar's shortcomings has been a restriction of its use, and consequently a reduction in its effectiveness in highway safety programs.

Determined to overcome the problems associated with the conventional police radar, manufacturers—with the blessing of the National Highway Traffic Safety Administration (NHTSA), Washington, D.C.—have exploited advances in electro-optics, signal processing, VLSI technology, and video recording. These new developments have yielded families of equipment for measuring vehicle speed that were not feasible even a decade ago.

Will the new technologies indeed overcome the shortcomings of present systems? Or will they simply replace them with new problems that will lead to new court challenges and thus further erode public confidence in the law enforcement community?

P. David Fisher Michigan State University

A review of the operation of conventional down-the-road radar and then a look at some of the more recently developed alternatives to it may help answer these questions. The alternatives include across-the-road radar, down-the-road laser systems, across-the-road lasers, and the use of auxiliary cameras. Cameras, it turns out, are useful for catching drivers who run red lights as well as speeders.

DOWN-THE-ROAD RADAR. The predominant radar in use today is down-the-road Doppler radar, in which the axis of the antenna is directed along the line of travel of the target vehicle [Fig. 1]. Its shortcomings, which have been well documented through numerous appellate court rulings, fit into two basic categories: improper target identification and spurious target-speed display readings [see table].

Identifying the target correctly can often be frustrating using down-the-road radar. Because the radar's range typically exceeds 800 meters and its half-power beamwidth is 0.21–0.31 radian, more than one vehicle is usually in the operational area of the radar beam at any given time.

But which vehicle's speed is being displayed? And how can the radar operator make that determination with a high degree of certainty? At present, the answer is to pay attention to the radar operator's target-tracking history.

> Ordinary radar is easily confused by too much traffic, but a laser can pick out a motorcycle at over 300 meters

All radar equipment in use today, besides having a digital readout to display target-vehicle speed, must provide a Doppler-audio output—an audible tone whose pitch correlates with the speed of the target vehicle, and whose clarity and loudness indicate the strength of the radar return from the target. The audio output may also indicate the presence of signals from multiple targets moving at different speeds.

To establish an acceptable target-tracking history, courts require that certain conditions be met. Michigan, for example, requires three conditions for stationary-mode operation. The radar operator must first have had a direct and unobstructed view of the target vehicle at the time the speed readings were acquired. Second, the Doppler audio output must have indicated that a dominant target signal was being processed. And, third, the radar operator's visual observation of the target vehicle, the sound made by the audio output, and the digital display of the target vehicle's speed all must have correlated for a sufficient period of time.

For moving-mode operation, a fourth element is also required: the patrol vehicle's speed, as measured by the vehicle's calibrated speedometer, must have correlated with its speed as measured by the radar device. (In moving mode, the radar measures the patrol vehicle's speed by processing radar reflections from the ground; the need to do that is one reason for its wide beamwidth.)

The second shortcoming of down-the-road radar—spurious speed readings—adds to the problems of target identification, and has resulted in numerous court challenges on its own. This shortcoming occurs because of electromagnetic and electromechanical interference effects: electromagnetic interfer-

Defining terms

Cosine effect: an effect that occurs with laser and radar speed-measuring devices whereby the measured speed and the actual speed are related by a factor equal to the cosine of the angle between the centerline of the beam and the line of travel of the target vehicle.

Doppler effect: the change in the observed frequency of a wave caused by a time rate of change in the distance between the source and the point of observation.

Doppler radar: a radar that exploits the Doppler effect to measure the radial component of the relative velocity between the radar system and the target vehicle.

Moving-mode operation: an operating mode in which the speed of the target vehicle can be measured while the measurement equipment is in motion—in a moving patrol vehicle, for example.

Stationary-mode or fixed-mode operation: an operating mode in which the speed of the target vehicle is measured while the measurement equipment is stationary.

Target-tracking history: the collective observations of the speed enforcement officer and speed-monitoring equipment. It is often used in court to determine whether the ticketed person should be held responsible for the traffic violation.

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ence generally caused by AM or FM transmitters operating in or near the patrol vehicle or from the patrol vehicle's electronic ignition system, and electromechanical interference typically caused by ventilation equipment within the patrol vehicle—the air conditioner blower, for example.

Designed to recognize AM and FM interference, modern radar equipment inhibits the radar from displaying any target-vehicle speeds when the interference is present. Moreover, well-trained radar operators are taught to recognize spurious readings due to interference and not to issue speeding tickets when interference is a problem.

Such target identification and interference effects clearly limit the usefulness of traditional police radar. Moreover, their effectiveness is further diminished by the widespread use of radar detectors.

To minimize these shortcomings, radar operators must be carefully trained, which adds to the costs of law enforcement. Hence, it is no surprise that law enforcement agencies are keenly interested in alternatives that counteract such drawbacks in a cost-effective manner.

VIDEO RECORDS. One method that has been proposed for overcoming the problems of down-the-road radar is to produce a video record of the speeding infraction along with a video record of the radar evidence. According to proponents of this approach, those records could be shown to the motorist at the time of the infraction with the intent of "selling the ticket," thereby reducing the chances that the citation would be appealed in court. Alternatively, the video record could be used to support or refute courtroom testimony.

Recently, CrimTec Corp., Auburn Hills, Mich., introduced a video incident capture system that integrates down-the-road Doppler radar with video technology to record simultaneously traffic flow and measured vehicle speeds. The video camera views traffic scenes while the radar device measures target-vehicle speeds. Both camera and radar are interfaced to video recording equipment, which captures the target-tracking history on VHS tape. In addition, a microphone enables the operator to add commentary to the tape and to pick up Doppler audio output signals from the radar.

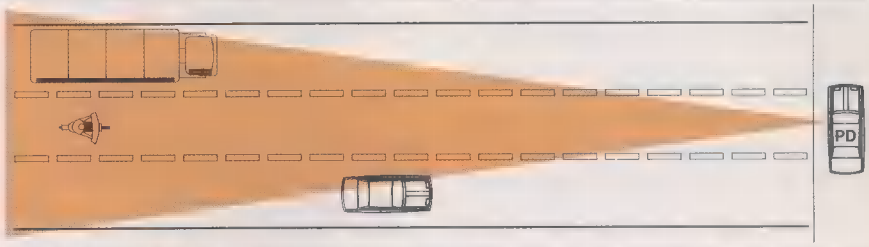
CrimTec claims that this technology offers several advantages over stand-alone Doppler radar. Specifically, it asserts that its equipment "creates a reliable witness" and will support the officer's testimony. Furthermore, company spokesmen believe that it will substantially reduce court time, enhance officer productivity, and reduce the number of citizen complaints.

However, while this technology does add a new dimension to recording the target-tracking history, it does not necessarily simplify target identification. Although the video record might support the officer's contention that the speed readings were not due to interference effects, video-recorded scenes lack the three-dimensional depth of view and other attributes the human operator can supply.

In particular, while the video incident capture system does provide much more information about the speeding case, it does not necessarily provide additional support for the officer's testimony, especially when multiple target vehicles are perceived on camera to be in the operational area of the radar.

In addition, because of its complexity, each system would cost much more to purchase and maintain than traditional police radar. Moreover, operator training would be more complex as well. And, finally, if cases involving video recordings were to go to

Down-the-road radar



[1] *The typical down-the-road radar beamwidth of 0.21 to 0.31 radian is exaggerated in this drawing to make the point that at a distance of just 100 meters, the beam subtends all three lanes of a highway. The police car in the drawing is parked on an overpass. The photograph shows a handheld down-the-road unit operating in stationary mode.*

Michigan State University

Alternative speed-measurement technologies

Type	Principle of operation	Moving-mode capability	Susceptibility to spurious readings due to interference	Detectability by the motorist	Training complexity
Down-the-road radar	Doppler	5	5	5	4
Video incident capture system	Doppler	5	2	5	5
Across-the-road radar	Doppler	3[a]	3	3	3
Photo-radar	Doppler	3	4	3	5
Down-the-road laser	Time-distance	1	1	1	2
Across-the-road laser	Time-distance	2[a]	1	1	1
Vascar[b]	Time-distance	4	1	1	2
Red-light camera	Position and time-distance	1	1	2	1

a Not currently implemented. Scale: 1 = Low, 5 = High.
b Visual average speed computing and recording.

trial, the trials would be far more complicated because many new items would have to be touched upon during the hearing—for example, what rules of evidence would need to be applied before the video record could be admitted as evidence in court.

ACROSS-THE-ROAD RADAR. Though the video incident capture system attempts to compensate for the inadequacies of conventional radar by creating a reliable witness, by itself it does nothing to simplify the capture of the target-tracking history or reduce the possibility that the speed reading was caused by some interference effect.

But other ways to deal with these problems with Doppler radar do exist. In many countries throughout the world, the Doppler principle is employed to measure vehicle speeds by directing the microwave beam across, instead of down, the road.

Across-the-road radar has one significant advantage over its down-the-road counterpart: the operational area of its beam is very small. Moreover, it is close to the radar unit [Fig. 2], which simplifies the target-tracking history since a given vehicle is within the operational area for only a short time. When no target vehicle is present, the radar display is blank.

For example, if the operational area extends 30 meters along the roadway and a target vehicle passes through this region at the speed limit of 90 km/h (25 meters/s), the vehicle will be in the operational area for only 1.2 seconds. That interval is short enough for it to be reasonably likely that only one vehicle will be in the beam at any time except when traffic volume is very heavy. That would not only reduce the target-identification problem, but would also lower the chances that the operator would confuse spurious display readings with *bona fide* target readings.

But there is an added complexity to across-the-road radar—the cosine effect. Doppler radar measures the projection of the speed of the target vehicle in the direction of the radar beam, not the actual speed of the target vehicle. That is, what is measured is the speed of the target vehicle multiplied by the cosine of the angle between the beam and the direction of motion. For down-the-road radar, the angle is close enough to zero to be ignored. But in across-the-road applications, it must be taken into account.

The radar device can correct for the cosine effect, but only if the angle is known. Thus, the cosine effect introduces a new uncertainty into the measurement process.

To minimize this uncertainty, across-the-road radars are typically fixed mounted. Then, after they are aligned (and at periodic intervals thereafter), test vehicles traveling at known speeds are driven through their operational areas to verify the alignment and overall accuracy of the system.

A number of international companies—including AWA Defense Industries Pty., Adelaide, South Australia; Zellweger Uster AG, Uster, Switzerland; M. Gatsonides & Sons, Overveen, the Netherlands; Sensyn Traffic, Gavle, Sweden; and Traffipax-Vertrieb, Düsseldorf, Germany—produce across-the-road radar units. And almost all of them produce fully automated versions, which not only measure target vehicle speeds but also provide a photo record of the speeding offense. Typically, the photographs obtained provide a view of the vehicle's license plate as well as its measured speed; the date, time, and location of the speeding offense; and the law enforcement officer's identification.

PRIVATE SPEED ENFORCEMENT. With police photo-radar equipment packages costing as much as US $100 000 per installation, manufacturers and suppliers of these systems have begun to provide traffic-monitoring services (TMSs) for a fee rather than selling the equipment outright.

> The major shortcoming of lasers and advanced radars is that they are hard to operate from a moving patrol car

Although TMSs are widely accepted throughout most of the world where speed-enforcement programs exist, they have only recently been introduced into the United States. Three U.S.-based companies currently offering these services are Traffic Monitoring Technologies of Friendswood, Texas; U.S. Public Technologies of San Diego, Calif.; and LeMarquis International Inc. of Garden City, N.Y.

The concept of privatizing speed enforcement is simple. The TMS supplier provides all the necessary equipment, including motor vehicles to house the apparatus, film, other supplies, and technical services. It also trains law enforcement personnel to operate the equipment.

In addition, it develops the film, prints the photographs, establishes the identity of the vehicle's owner, and prepares and mails the speeding ticket. It also provides expert witness testimony if a ticket is challenged in court.

Typically, the TMS supplier receives a fee only if the ticket is paid—around $15 to $25 per ticket. Traffic Monitoring Technologies is currently providing these services in Paradise Valley and Peoria, Ariz., and in Pasadena, Calif.

The primary hurdle that must be cleared before this technology will see widespread use in the United States is lack of public and court acceptance of it. Current pilot studies being carried out with grants from the NHTSA are intended to identify the issues that still need to be resolved before these technologies can be endorsed by Federal agencies like the NHTSA.

DOWN-THE-ROAD LASERS. Recently, two companies—Laser Technology Inc. of Englewood, Colo., and Kustom Signals Inc. of Lenexa, Kan.—have begun to market worldwide a new class of speed-detection device that attempts to overcome the inherent deficiencies of down-the-road Doppler radar. These new devices, which emit a 3-to-4-milliradian infrared laser beam, operate on a totally different principle from Doppler radar and are much less likely to display spurious target-speed readings because of interference effects.

Their narrow beams enable speed-enforcement officers to isolate single target vehicles at distances exceeding 300 meters [Fig. 3]. And the infrared laser beam is not detectable by radar detectors currently on the market.

Moreover, while it is conceivable that such a laser detector could be produced, it would not be very effective since the laser is an instant-on device with little propagation beyond the target vehicle if the laser is properly aimed. In most cases, therefore, the user of a laser detector would get little or no warning that a laser speed measurement device was being operated nearby.

These laser devices operate on the time-distance (pulsed-radar) principle, which uses nanosecond-wide pulses of infrared energy to measure the range to the target vehicle at 10-ms intervals. The change in range during the interval divided by the interval itself is a measure of the vehicle's speed. That sequence of measurements establishes a history of the speed of the target vehicle, which can be displayed on a numerical readout.

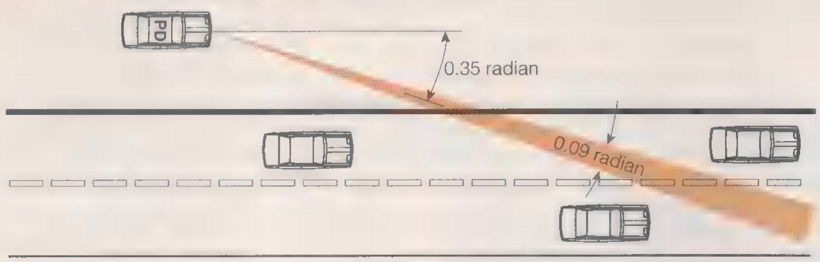
Since a vehicle traveling at a typical speed limit of 90 km/h will cover only a quarter of a meter in 10 ms, the round-trip delay difference between two consecutive readings will be approximately 1.7 ns. Clearly, subnanosecond accuracies are required in measuring this difference to ensure that target vehicle speeds in the range of 8–240 kilometers per hour can be gauged with an error not exceeding 1 km/h.

The requisite accuracy is achieved by transmitting a burst of pulses over a few tenths of a second and then performing a regression analysis on the measured delays. If the results of the regression analysis pass a pre-established accuracy test, the speed is accepted and displayed.

In this example, two principal assumptions were made: first, that the laser unit was held stationary while the readings were being made (since all vehicle-speed measurements are actually made relative to the speed of the detection device itself) and second, that the light pulses would all strike a flat surface perpendicular to the path of the light wave.

While the first assumption presents no

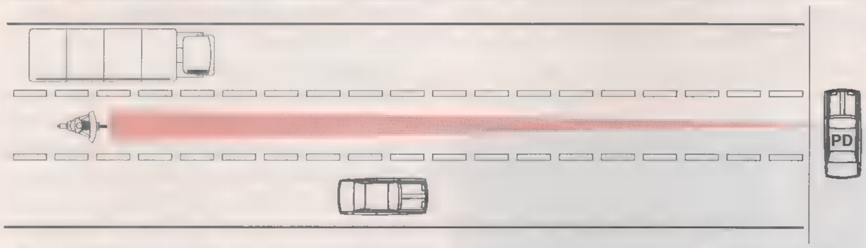
Across-the-road radar



[2] Because of its narrow beamwidth and 0.35-radian angle to the road, across-the-road radar usually has only one vehicle at ■ time within its operational area. The photograph was taken by a camera mounted in a police car and triggered by an across-the-road radar. Note the readout of pertinent data, including date, time, and target-vehicle speed.

LeMarquis International Inc.

Down-the-road laser



[3] The extremely narrow beam of a down-the-road laser system (3–4 milliradians) allows speed-enforcement officers to isolate individual target vehicles at distances exceeding 300 meters. The photograph shows the author checking out a down-the-road laser system.

Michigan State University

problem (the instrument is simply used in the stationary mode), the same cannot be said of the second. In practice, the waves strike the front or rear of the target vehicle, both of which are irregular surfaces. The result is ■ reflected light pulse that is dispersed in the time domain due to the different transit times for different portions of the reflected beam. It is also dispersed in angle. Hence, multiple reflections from neighboring objects can further confuse the measurement.

Dealing with the possibility of errors caused by beam dispersion places extra requirements on the optical and signal-processing portions of the laser system. Basically, the system must detect invalid measurement conditions and not display a speed reading under those conditions.

In fact, laboratory and field tests conducted on laser systems indicate that they are accurate and simple to operate. Moreover, they do indeed overcome ■ number of the shortcomings of traditional police radar.

For instance, laser systems greatly simplify the business of target identification since their beams can be directed to an individual vehicle with only that vehicle's speed being measured. Such precision does have one drawback, however: for distances of more than ■ couple of hundred meters, it is difficult to keep the beam trained on a target vehicle without a tripod or other steadying device. Of course, that does not compromise the accuracy of the device, only its ability to acquire target vehicle speeds.

Very short distances also present a problem because of the cosine effect. To operate the device, an operator must be off to the side of the road or on an overpass above the roadway. For short distances, the cosine of the angle between the direction of travel and the infrared beam may become significant, and the measured speed may be significantly lower than the actual speed. For laser units positioned 4 meters off to the side of the road, that source of error can be kept below 1 percent by restricting operation to distances greater than about 30 meters (angles less than about 0.13 radian).

The major shortcoming of laser speed-measuring equipment is its inability to be used in the moving mode, which most law enforcement personnel clearly prefer. Several important technical problems will have to be overcome before a laser system can be operated in the moving mode.

Even if the patrol-vehicle speed could be measured by another means and then electronically entered into the laser system, properly aiming the narrow laser beam while moving would still be ■ problem—apparently an extremely difficult one to solve.

ACROSS-THE-ROAD LASER. In contrast with down-the-road laser devices, which must be carefully aimed at the target vehicle, the Autovelox 104-C across-the-road laser system need not be aimed at all after it has been set up alongside a road. Built by Sodi Scientifica SpA, of Florence, Italy, it employs two

infrared laser beams and operates on the time-distance principle [Fig. 4].

Its lasers are mounted on a horizontal bar and emit parallel light beams that are separated by 0.4 meter. Adjacent to each laser on the bar is a detector, which measures the amount of light reflected back to the instrument. The equipment directs the beams across the roadway perpendicular to the direction of traffic flow. To eliminate interference effects between the two beams of light, each beam is independently pulse modulated .

A beam detects a vehicle by sensing changes in the intensity of the reflected light. Since the distance between the beams is known, the transit time for the front edge of the vehicle to pass from beam to beam is easily converted into a speed measurement by dividing it into that known distance of 0.4 meter. As an example, a measured interval of 15 ms corresponds to a vehicle speed of 96 km/h.

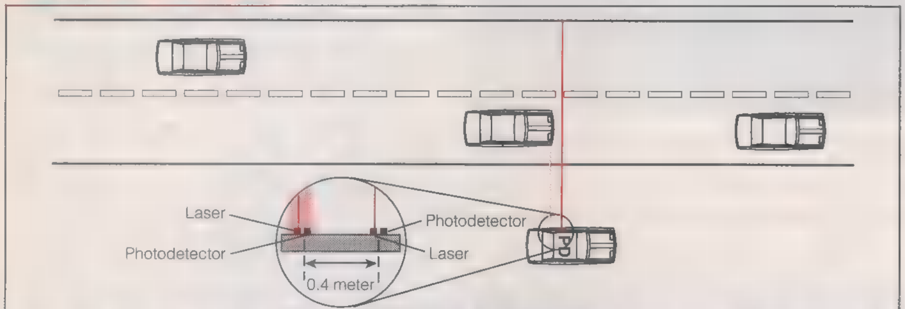
To prevent errors due to multiple lanes of traffic, the Autovelox-C actually measures a car's speed twice—when the vehicle enters the laser system's operational area and when it leaves. If the two readings do not match within a very tight tolerance, the reading is rejected. Thus, if two cars in adjacent lanes overlap each other, no reading will result unless the cars happen to be moving at almost identical speeds.

The Autovelox 104-C uses a palmtop computer as a handheld controller for displaying vehicle speeds and programming several other features and options. One of its options automatically radios the measured speeds down the road to a strategic "stop point," where waiting law enforcement officers can wave over speeders. This feature might be used in conjunction with radio voice transmissions that provide a description of the speeding vehicle.

With another option, a camera can be interfaced to the laser system, and the vehicle's speed automatically recorded on 35-mm film. Superimposed on the film would be a view of the vehicle's license plate, the vehicle's measured speed, and the date, time, and location of the speeding offense. With any of the options, this across-the-road laser device can be operated during both daylight and nighttime hours.

PASSIVE MONITORING. Down-the-road and across-the-road radar and laser devices are active devices because they transmit microwave or optical energy. By contrast, Vascar, or visual average speed computing and recording, is passive.

Across-the-road laser



Sodi Scientific SpA

[4] This across-the-road laser system is inherently resistant to false readings. If it is not positioned at exactly right angles to the roadway or if its beams are not aligned properly, the reflected beams will miss the photodetectors, and no reading will be generated.

Manufactured by Traffic Safety Systems of Richmond, Va., Vascar relies on visual observations by law enforcement officers for its input. It operates on the time-distance principle and may be operated in either the stationary or moving mode. Distances may be programmed into the device via a thumbwheel switch or measured using a transducer connected to the patrol vehicle's transmission. The transducer produces 10 000 pulses per mile (0.161 meter per pulse).

In monitoring traffic and clocking suspected speeders, the law enforcement officer measures the time it takes them to travel a known distance. When the motorist enters the operational area for a clocking, the Vascar operator throws a switch to start measuring the time interval. And, when the vehicle leaves the operational area, a stop switch is thrown. Vascar automatically determines the speed of the target vehicle by computing the ratio of the distance traveled to the lapsed time and displays this speed on a digital readout.

Less efficient and more operator-intensive than its active speed-measurement device counterparts, Vascar nevertheless provides a viable option for some law enforcement agencies. It is more flexible and less costly than across-the-road radar or laser devices, which can only be operated in the stationary mode. Moreover, it does not possess the target identification or interference problems encountered with down-the-road radar devices.

The principal shortcomings of Vascar—that is, the points most often cited in courtroom defenses—relate to the accuracy of the equipment and the possibility of human error in establishing either the distance or lapsed-time parameters.

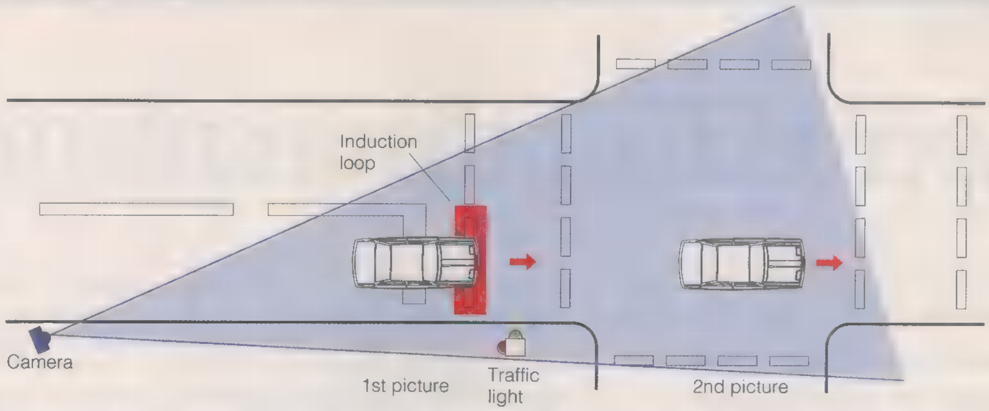
Vascar devices do include a means for verifying that the distance measurement, lapsed-time measurement, computational circuitry, and display circuitry are in proper working order. Hence, if the Vascar operator documents this verification process at the beginning and end of the shift in which the device is used, the only remaining defense relates to the possibility of operator error.

Here the training and experience of the Vascar operator weighs heavily, as does the specific nature of the clocking. For example, if the clocking distance is too short or if the operator does not have a good view of the beginning or ending positions for the operational area, then human error could result in an inaccurate clocking.

FOCUSING ON RED LIGHTS. None of the devices described thus far would be useful for determining whether a vehicle ran a red light. Yet that is an important highway safety problem in many urban areas.

For example, in New York City, nearly 60 percent of the 691 traffic fatalities in 1990 were due to traffic crashes at intersections where traffic lights exist. Because of that statistic, New York City undertook a pilot

[5] Triggered by the buried induction loop, the red-light surveillance camera takes two pictures, 0.6 second apart, whenever a vehicle enters the intersection while the light is red. The fourth data column in the photographs indicates that photo 233A was taken 0.4 second into the light's red phase and photo 233B was taken at 1.01 seconds.



LeMarquis International Inc. (photos)

highway safety program late in 1991 to reduce such crashes by installing red-light surveillance cameras. The technology, which is employed in over 40 countries, uses sensors linked to traffic signals to detect and photograph license plates of vehicles that run red lights [Fig. 5].

The systems use cameras activated by magnetic induction loops embedded in the pavement. When a vehicle enters the intersection after the traffic light signal has turned red, a fully automated camera takes two photographs in succession with a known delay time between exposures.

These two photographs provide indisputable evidence that the motor vehicle ran the red light, since both pictures show the position of the vehicle in the intersection as well as the traffic light being red for both instants in time—as well as the date, time, and location of the infraction. The exposed film is collected at regular intervals and delivered to a development facility with a camera and film log.

Upon receipt of the uncut film roll, a technician for a traffic-monitoring system supplier—like LeMarquis International—reviews the film on an electronic image viewer. Where the issuance of a liability notice is appropriate, the technician prints out two copies of the images, zooming in on the license plate. The license plate number is checked against files from the Department of Motor Vehicles to determine the vehicle owner, the owner's address, and the vehicle description. Finally, a set of images is forwarded to the vehicle owner.

Administrative law judges are available to all summons recipients who dispute the violation. Currently in New York City, these violations are processed as civil infractions in a manner identical to parking tickets.

Based on totals that showed that New York City police issued 344 000 traffic tickets for red-light violations in 1990, LeMarquis International estimates that placing 1000 red-light cameras at the city's 300 or 400 most dangerous intersections would generate an estimated gross income of $420 million per year and an annual net income to the city in excess of $265 million.

Of course, the success of such a program should not be measured by the revenues generated, but by the reduction in the number and severity of crashes at intersections with red lights—with the most critical measure being the reduction in the number of fatalities. However, the cameras themselves are unable to reduce the number of crashes; rather, their presence, coupled with widespread efforts to inform the motoring public about them, could substantially reduce the number of crashes.

TO PROBE FURTHER. "Shortcomings of radar speed measurement," by P.D. Fisher [*IEEE Spectrum*, December 1980, pp. 28–31] describes the operational characteristics of police traffic radar for both stationary- and moving-mode operation. It examines the trustworthiness of these devices and discusses the rationale for establishing national equipment standards and operator training standards.

A report, "Model Minimum Performance Specifications for Police Traffic Radar Devices," U.S. Department of Transportation, No. DOT HS-807-415 (May 1989), establishes a set of radar equipment specifications that has been adopted by the International Association of Chiefs of Police, Arlington, Va. The specifications serve as a benchmark that guides the development of alternative technologies.

Defense of Speeding, Reckless Driving and Vehicular Homicide, by J. F. Campbell, P. D. Fisher, and D. A. Mansfield (Matthew Bender, New York, 1984) is a reference book written primarily for judges, prosecutors, and defense attorneys. For each class of speed-measurement device, it describes the scientific principle of operation, operational characteristics, operating procedures, and the potential for speed-measurement errors. Key court rulings are also interpreted.

ABOUT THE AUTHOR. P. David Fisher (SM) is a professor of electrical engineering at Michigan State University in East Lansing and a registered professional engineer with research interests in instrumentation and computer engineering. He developed a national police traffic radar testing laboratory approved by the National Institute of Standards and Technology, Gaithersburg, Md. Since 1981, the laboratory has tested over 7000 radar devices.

Approaching the quantum limit

In devices with features smaller than 0.1 micrometer, electrons behave more like waves in waveguides than like particles

As technology drives semiconductor geometries ever deeper into the nanometer domain, the phenomena of classical physics go into retreat. When device features reach about 5 nm, electrons start behaving more like waves than particles, and so react to waveguiding and interference effects. Also, the single discrete charge comes to be felt, changing the well-known macroscopic nature of resistance, capacitance, and inductance to a more exotic microscopic one. Indeed, wholly new electronic mechanisms emerge, including new transistor principles.

These quantum phenomena are as important in silicon as in gallium arsenide. Many have now been observed in the laboratory. Although few are yet robust enough for commercial applications, all are fascinating, and some may be the basis of a new electronics revolution in the next century. Meanwhile, the new physical phenomena as well as quantum theory are suggesting novel concepts to test in ultrasmall devices.

Most useful semiconductor devices switch on command from one electric state to another within a billionth of a second. Conventional transistors are based on one of two principles. For bipolar transistors, the basic mechanism is minority carrier injection: the injection of negatively charged electrons from an emitter electrode into and beyond a region where the current is conducted primarily by positively charged holes (electron vacancies), or vice versa. Field-effect transistors (FETs), on the other hand, are based on the opening and closing of a conducting channel by the influence of an electric field from a voltage on a gate electrode. The discovery of those two effects launched the microelectronics revolution.

Karl Hess University of Illinois
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Although many silicon IC applications are still evolving, it is clear that current very large-scale/very high-speed integrated-circuit (VLSI/VHSIC) technologies will eventually reach their limits. Those limits are set by several practical and fundamental barriers.

LIMITS TO SHRINKAGE. On the practical side appear difficulties with interconnects, such as the higher resistance of narrower connections. According to some researchers, those problems may limit useful devices to dimensions of 0.1 micrometer or larger.

The fundamental barriers are imposed by the laws of quantum mechanics. It has long been known that the electrons induced by the field effect in metal oxide semiconductor (MOS) transistors are confined by a potential barrier created by the gate voltage to a depth of less than 10 nm in the direction perpendicular to the oxide-semiconductor interface. Each confined electron behaves like the basic quantum-mechanical "particle in a box": it exhibits an energy higher than it would if it were free to roam throughout the crystal.

This phenomenon, known as size quantization, is fundamental to nature: when an electron is confined to a box of a certain length, that length will be a multiple of the electron's associated de Broglie waves (probability amplitude of being found).

> In principle, the wavelike nature of the electron can give rise to new devices

So far, size quantization has not radically altered the design of ever-smaller transistors because the laws of transistor function are still governed by the requirement of overall charge neutrality. In fact, size quantization in the dimension perpendicular to the oxide-semiconductor interface often improves matters by giving electrons greater mobility and smaller effective mass.

Once features become smaller than 5 nm, however, quantum effects from the wavelike nature of the electron become very important, even at room temperature—restricting the scaling down of device dimensions.

First, if the electron is confined to a region smaller than 5 nm, the spacing of the allowed energy levels becomes much greater than the thermal energy of the electron. Thus the electron, if it recombines with a hole, will emit a shorter wavelength of light than if it were free in the crystal.

Second, if the oxide "wall" (potential barrier) confining the electrons itself becomes thinner than 5 nm, then electrons can tunnel through the oxide: that is, the electrons start "leaking out" of their potential-barrier quantum-mechanical box.

Third, in either case, the electron begins to exhibit interference effects analogous to those in optics: an electron wave can reflect from obstacles, can be "split" and take two or more paths (like a photon wave through a beam splitter), and can interfere with itself constructively and destructively.

Moreover, in structures even larger than 5 nm, the discreteness of charge coarsens response. Consider, for example, an MOS transistor with a square gate 0.1 μm on a side and an oxide layer 5 nm thick. At a voltage of 1 V, only 300 electrons reside in the inversion layer under the gate; therefore, a fluctuation of only 30 electrons will give rise

Defining terms

Coulomb blockade: the blocking of tunneling due to the energy needed by an electron to propagate from one side of a capacitor to the other.

Mesoscopic structure: a three-dimensional structure smaller than an electron's phase coherence length but larger than atoms or small molecules. At cryogenic temperatures and low bias voltages, a mesoscopic structure may be micrometers across; at room temperature, it is of the order of 10 nanometers. One example is a quantum dot.

Phase coherence length: the maximum length in any material over which the phase of the electron's wave is conserved.

Quantum interference: interference effects, analogous to those in optics, when alternative paths are available for propagation of the electron wave function within the phase coherence length.

Size quantization: the increase in energy of the allowed states of an electron as a result of its being confined to a region (such as a mesoscopic structure) smaller than its phase coherence length.

Transmission mode: sine-like standing-wave pattern transverse (perpendicular) to the electron wave's direction of propagation through a mesoscopic structure; the electron wave function's modes are much like the modes of a waveguide for electromagnetic fields or of an optical fiber for light.

Tunneling: the passage of an electron (or any particle) at a given energy through a potential barrier having a higher energy than itself, owing to the barrier's being too thin to fully confine the particle.

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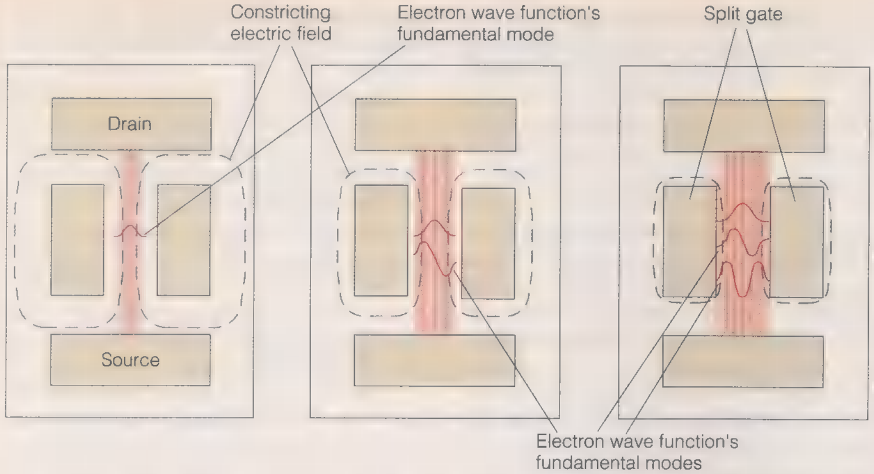


[1] A constriction device—essentially a field-effect transistor with its gate split in half—displays quantized behavior: electrons behave like waves propagating through a waveguide in various modes, much as modes of light propagate through semiconductor lasers or optical fibers. Here a constriction device is shown from the top. When a negative voltage is applied to both halves of the split gate, the resultant electric field [dashed lines] repels electrons traveling from source to drain, restricting them to a thin central channel. As the electric field weakens [left to right], the channel widens, admitting more modes. The modes are typically a sine-like standing-wave pattern transverse (perpendicular) to the electron wave function's direction of propagation. Note that part of the wave can penetrate the repelling electric fields. The fundamental mode is one in which half a wavelength (having one maximum) will fit in the constricted channel. Higher-order modes have more than one maximum, producing an electron wave with a number of amplitude maxima [shown as regions of darker color].

to voltage fluctuations of 0.1 V!

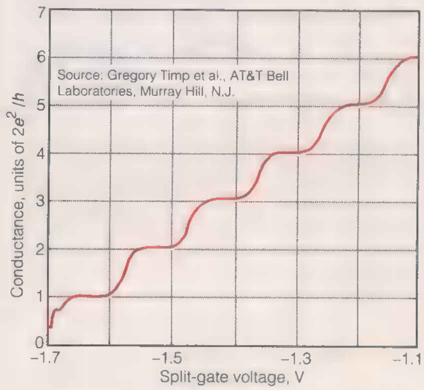
Certainly silicon technology has yet to arrive at those dimensions. But it is clear that the fundamental limit of single charges—the absolute lower limit of all possibilities—is close. Current research already allows a glimpse into the realm of quantum transport and single-electron devices.

THE MESOSCALE. Size quantization in FETs has valuable effects such as the high electron mobility in modulation-doped structures [''Quantum tailored solid-state devices,'' by Timothy Drummond et al., *IEEE Spectrum*, June 1988, pp. 33–37].

From an engineering point of view, however, there has been no revolutionary change in the operating principle of transistors incorporating such structures as quantum wells. Although the electrons are quasi-two-dimensional, they still can be treated in the remaining third dimension by classical transport concepts (such as the current-continuity equations or the Boltzmann equation), with a few modifications to include specifics of a band structure or Fermi statistics (the Pauli exclusion principle).

But as soon as quantum (wavelike) effects become important in all three dimensions, everything changes. The device structure can be still fairly large—containing thousands of atoms—and is therefore often called mesoscopic (between atomic and macroscopic in scale). The defining characteristic of a mesoscopic structure is that the phase coherence of an electron within the structure remains unbroken until it reaches an electric contact. In other words, a mesoscopic structure is any structure smaller than the mean free path for phase-breaking events (mostly inelastic collisions between the electron traveling through the structure and imperfections in the structure's crystal lattice).

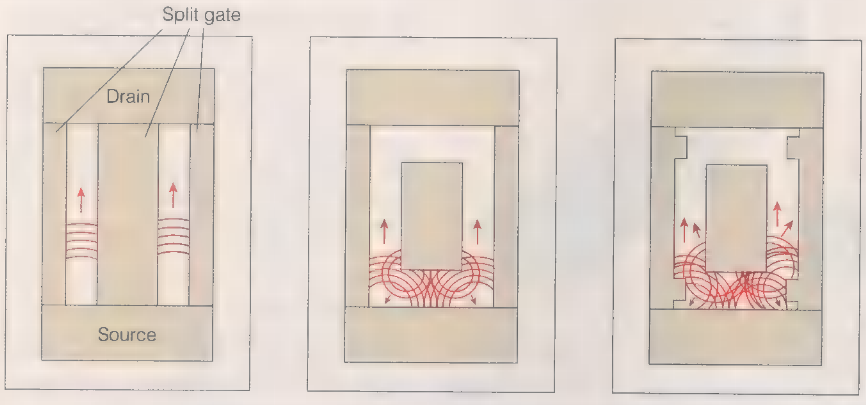
In a mesoscopic structure, quantum mechanics rules, and it becomes very difficult to answer the electrical engineer's standard questions as to what represents resistance, capacitance, or inductance.



[2] Conductance of the central channel of a constriction device, when plotted against the voltage of the split gate, decreases in a steplike pattern. Each step (its resistance about 13 kΩ) corresponds to a multiple of $2e^2/h$, where e is the charge on the electron and h is Planck's constant. That amount would be expected if each step corresponded to the addition of a transmission mode for the electron wave function. This experiment, conducted by Gregory Timp and his colleagues at AT&T Bell Laboratories in Murray Hill, N.J., in 1990, confirmed the wavelike behavior of electrons in small structures and the constriction device's waveguide characteristics.

STEPS TO UNDERSTANDING. Rolf Landauer and Markus Büttiker, from IBM Corp.'s Thomas J. Watson Research Center at Yorktown Heights, N.Y., have pioneered a technique for making reasonably simple estimates of the electrical properties of a mesoscopic structure. Landauer treats the mesoscopic structure as an object that scatters the electron and leads to a reflected and transmitted electron wave. The transmission coefficient can be calculated from the Schrödinger equation (the basic quantum-mechanical equation describing the wave function).

According to Landauer and Büttiker, the electrical conductance of the mesoscopic structure should be equal to this transmission coefficient divided by the quantum resistance $h/2e^2$, which is roughly equal to



[3] Conductances of parallel constrictions need not add, as in the macroscopic world, and in fact do so only where all the constrictions are directly connected to the contacts [left] and the two channels are independent. In that case, the phase of the electron's wave function in the different channels is not correlated. But if the channels are part of one phase-coherent mesoscopic structure [middle and right], the conductances do not add. Instead, the wavelike electrons more resemble electromagnetic waves in a waveguide, exhibiting interference. Projections in the channels [right] cause the wave function to be reflected into both channels, which cease to be independent. A good schematic analogy is waves on the surface of water.

about 13 kΩ, with h being Planck's constant and e the electron's charge. Landauer's technique shows that resistance comes in quantized lumps of 13 kΩ per transmission mode. Electrons behaving like waves propagate in various modes, which are in complete analogy to the modes displayed by photons in optical fibers [''Fiber optics,'' *Spectrum*, silver anniversary issue, 1988, pp. 97–102].

These theoretical predictions by Landauer and Büttiker have been experimentally verified. The conductance steps were discovered in 1988 by Bart Van Wees and his coworkers at Philips Research Laboratories, Eindhoven, the Netherlands, and by David A. Wharam and his colleagues at the universities of Cambridge, Munich, and Uppsala and at Cavendish Laboratory in Cambridge.

Shortly thereafter, Gregory Timp and his co-workers at AT&T Bell Laboratories in Murray Hill, N.J., more precisely quantified the conductance steps. They built an aluminum gallium arsenide diode with a variable constriction between two contacts, created by a gate split in half [Fig. 1]. The number of transmission modes of the electrons passing through the constriction depends on the voltage applied to the split gate. The conductance of the constricted region is then indeed quantized in multiples of $2e^2/h$, corresponding to a resistance of about 13 kΩ.

YES AND NO. The steplike nature of conductance [Fig. 2] contrasts with the classical continuous decrease of conductance (increase of resistance) with decreasing size of the constriction. That result is only one astonishing feature of the mesoscale.

Go a bit further and consider what happens with two constrictions in parallel. Do the conductances add, as is usual? The answer is both yes and no!

The answer is yes, if the constricted regions are directly connected to the reservoirs or contacts where many scattering centers break the phase of the wave functions and make the electrons appear like classical particles.

The answer is no, however, if the constrictions are connected to a common area where the electrons still exhibit phase coherence (that is, where no semiconductor crystal impurities or lattice vibrations disturb the electron) [Fig. 3]. In this case, the lengths of the two constrictions with respect to the size of the mesoscopic system will determine the result. Similar effects are known for electromagnetic waves in waveguides.

NEW MECHANISMS. The wavelike nature of the electron not only gives rise to strange behavior—in principle, it could also yield new mechanisms for device applications.

One feature that has excited several researchers is the close resemblance mesoscopic systems bear to waveguides. Unlike the metallic boundaries in electromagnetic waveguides, however, the boundaries of mesoscopic systems can be easily controlled by the application of external potentials (such as the voltage on a split gate). Therefore, mesoscopic structures may often be viewed as waveguides whose size can be changed suddenly.

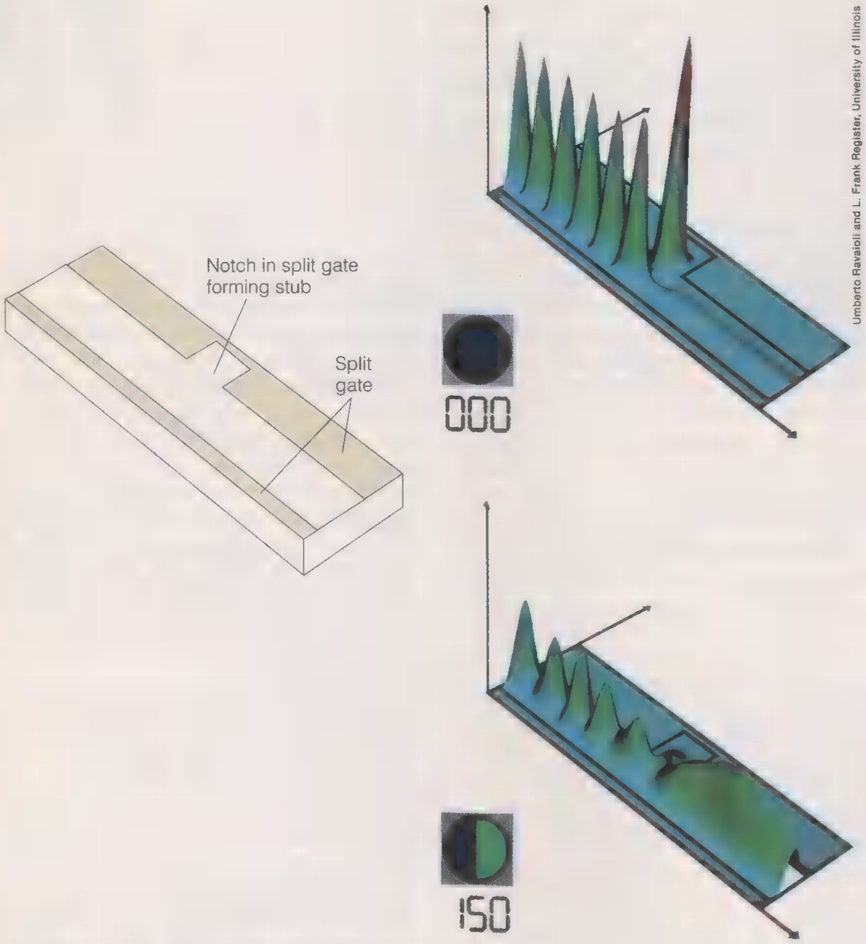
Take the mesoscopic analog of a stub tuner: a waveguide with a side stub of variable length. The stub is created by a notch in one side of the split gate. The stub's effective length is controlled by the split-gate voltage, which creates a potential barrier that lets the electrons propagate only so far. But odd things happen to the wave function in the main arm if the effective length of the stub is changed by a few nanometers by a instantaneous change in the voltage [Fig. 4].

Before the change in stub length, the electron wave function does not penetrate half of the main arm, because it interferes destructively with reflections from the side stub. After the stub length changes, the interference becomes constructive and the electron wave proceeds in the main arm.

In other words, a current has been switched on by remote control of the quantum interference. This is a new transistor principle, one that has been put forth independently by Alan B. Fowler, an IBM Fellow from the center in Yorktown Heights, N.Y.; Supriyo Datta, professor of electrical engineering at Purdue University; and a group at the University of Illinois, including one of the authors (Hess).

Whether or not this transistor effect will be useful in electronics, it indicates the kind of new opportunities afforded by mesoscopic systems: waveguides that can change their properties through alterations of boundaries on a femtosecond scale.

High switching speed is another possibility. An electronic switch the size of a molecule can be shown to switch charge state in about 0.01 picosecond (this follows from the 13-kΩ value of the quantum resistance times the molecular capacitance). The same switch changes molecular capacitance (which is about 0.1 attofarad, or 10^{-19} farad)



Umberto Ravaioli and L. Frank Register, University of Illinois

[4] In principle, an electronic stub tuner is a novel transistor based on a quantum interference effect. The stub tuner is a waveguide with a side stub of variable length. In a mesoscopic device—one smaller than the distance over which an electron's phase is conserved—the stub can be defined by a notch cut out of one side of a split gate [left]. Then the effective length of the stub is controlled by the voltage on the stub gate. This voltage can be adjusted to stop the electron wave function from penetrating the right half of the main arm because it is destroyed by interference with reflections from the stub, as shown in a computer simulation [top right]; in that case, the wave function on the left forms a standing wave (many maxima). Changing the voltage on the stub gate alters the effective length of the stub; the interference becomes constructive, and within 150 femtoseconds, the electron wave function enters the other half of the main arm [bottom right] as a propagating wave (hump).

two orders of magnitude faster than the speed of the fastest known high-electron-mobility transistor.

TECHNICAL DIFFICULTIES. The bad news is, the huge speed advantage is lost because the molecule in question is coupled in parallel with a capacitive environment much larger than its own. Environmental parasitics are one of the big challenges to be overcome if electronics on the molecular scale are to be practical.

Other technological problems are created by the size of the stub tuner: only at very low temperatures—about 1 K—can the size be in the micrometer range. For it to work at room temperature (that is, to keep the phase coherence of the electrons), the stub tuner needs to be shrunk to about 10 nm in all dimensions.

Still, such a size is not impossible. At least one mesoscopic device with features only 10 nm across in at least one direction has already been built and operated at room temperature. This device is the resonant tunneling diode introduced two decades ago by Leo Esaki and Ray Tsu at IBM Corp. Gerhard Sollner and co-workers at Lincoln Laboratory in Lexington, Mass., have fabricated resonant tunneling diodes with operating speeds close to the picosecond (or inverse terahertz) range. Transistors and more novel devices using resonant tunneling structures have also been fabricated by Federico Capasso and his co-workers at AT&T Bell Laboratories in Murray Hill and by Naoki Yokoyama at Fujitsu's Atsugi Laboratories in Atsugi City.

Many difficulties hinder economic evaluation of these effects. For example, the quantum interference effect is weak. It is disturbed or even destroyed by such imperfections of the crystal as impurities, the unavoidable lattice vibrations, and the other conduction-band electrons. Thus, the master principle of the T-shaped transistor falls far short of conventional transistors, which largely depend on overall charge neutrality.

Other effects peculiar to mesoscopic systems may be more robust and promise commercially useful devices. One is the combination of a quantum effect and a coulombic effect: the Coulomb blockade. It is this discovery that has led to an experimental transistor that can control the passage of individual electrons.

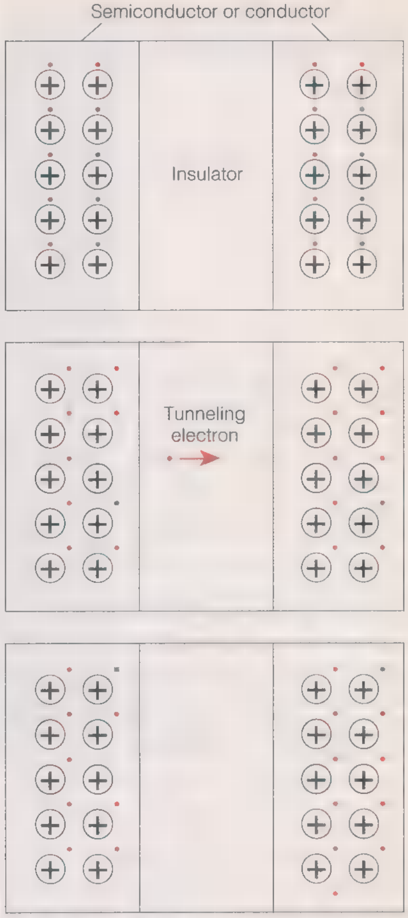
COULOMB BLOCKADE. This effect is based on principles that, except for the quantum-mechanical mechanism of tunneling, Michael Faraday could have understood. In fact, the Coulomb blockade is elementary, although it has been found only recently.

Consider a metal wire interrupted by a thin insulating region, such as silicon dioxide, air, vacuum or the like [Fig. 5]. The metal wire consists of positive ions and (negative) electrons that, by the source of the current, are slightly displaced or separated from one another toward opposite ends of the metal. This slight separation of the two polarities gives rise to a polarization charge, which can be varied by a change in the current. An electron in the insulating region will then "feel" a certain force due to the polarization charge.

The two ends of the wire separated by an insulating region represent, of course, a capacitance. More important for the single-electron transistor, the insulating region also forms a junction through which—if it is narrow enough—the electron can tunnel. Now, say that one of the electrons in the wire tunnels through to the other side; what happens to the energy stored in the capacitor? As always, the energy change is inversely proportional to the capacitance.

For most purposes, the change of energy of a capacitor by the transfer of a single electron may be neglected since it is small compared to the thermal energy. But if the capacitance is very small (of the order of an attofarad) and/or the temperature is very low (that of liquid helium, 4.2 K), the change in energy from the transfer of a single electron becomes crucial. In fact, for very small values of the polarization charge—about half an electron charge or smaller—a single electron's tunneling can stop current flow: the tunneling of subsequent electrons is blocked by an energy barrier introduced by the Coulomb interactions. This energy barrier has come to be called a Coulomb blockade.

The Coulomb blockade can be engineered to be as narrow or as wide as needed: it is inversely proportional to the capacitance



[5] Coulomb blockade is a combination of a quantum effect (tunneling) with a classical effect (charging energy); it becomes important in very small capacitors (of around 1 attofarad). The insulating region forms a junction through which an electron can tunnel if the distance between the two conducting regions is small (typically below 5 nanometers). If no current is applied to the capacitor, electrons lack the necessary energy to tunnel [top]. If any current is applied, however, the negative electrons (red dots) are slightly displaced or separated from the positive ions (black pluses) in the conducting crystal lattice [middle]. This separation of the polarities gives rise to a polarization charge, which can be varied by the current source. Once the polarization charge reaches half an electron charge, no additional energy is required for an electron to tunnel through the insulating region. But the event of tunneling can recharge the junction so much that the voltage across it drops and no other electron is allowed to follow, blocking current [bottom].

Dreams and realities

In 1959, the famed California Institute of Technology physicist Richard Feynman gave a presentation entitled "There's Plenty of Room at the Bottom," published later in the February 1960 issue of the Pasadena institute's magazine *Engineering and Science*. In the classic talk, Feynman issued "an invitation to enter a new field of physics" that embraced solid-state physics on the scale of individual atoms.

Feynman was, of course, prompted by the brilliant research on transistor action announced by John Bardeen, Walter H. Brattain, and William B. Shockley in 1947, which set in motion the solid-state miniaturization of electronics. Central to Feynman's talk were the "bottomless" possibilities of "manipulating and controlling things on a small scale," with particular regard to encoding information into solid material, or better yet, solid-state circuits.

Feynman maintained that writing the Lord's Prayer on the head of a pin was the "most primitive walking step" toward writing the entire *Encyclopaedia Britannica* on the same head of the pin, and would ultimately lead to the possibility of scribing all the books in the world on just a few square centimeters.

Feynman's vision was right on. Over the past two decades, the stunning achievements of lithography and nanofabrication technology, along with the recent developments of scanning tunneling microscopy and near-field optics, have by now made it possible to tailor the structure of materials literally atom by atom. Such capability has never before been available, except through naturally occurring atomic and molecular processes mostly in biology. Beyond the exploration of physics and a physicist's dream, there are now new engineering solutions to all the possibilities proposed by Richard Feynman three decades ago. *-K.H. and G.J.I.*

across the gap. For operation at room temperature, the capacitance must be of the order of 1 aF. At the same time, the capacitance across the gap must be larger than the distributed capacitance of the wire: otherwise the system will not work at all. In short, a Coulomb blockade requires ultrasmall and carefully designed tunnel junctions. The Coulomb blockade has been experimentally confirmed by many experimenters. A three-terminal version, the single-electron transistor, has been proposed by, among others, Konstantin Likharev and his co-workers in Moscow.

SINGLE-ELECTRON TRANSISTORS. The single-electron transistor consists of two horizontal Coulomb blockade tunnel junctions [Fig. 6]. The gate electrode between the two blockades determines the polarization charge that is crucial for the transfer through the tunnel junctions. Thus, the charge of the center "gate capacitor" controls the current flow through the tunnel junctions.

It has been experimentally proven that the transfer of single electrons can be controlled in this way. In principle, a single electron can carry 1 bit of information, certainly the most economic way of information storage and transfer imaginable. One of the early single-electron transistors built by a group at the Massachusetts Institute of Technology was about 1 μm on a side. The most recent tunnel junctions used by Likharev (who is now at the State University at Stony Brook, N.Y.) and his co-workers have feature sizes as small as 80 by 60 nm.

Quantum interference devices, such as resonant tunneling diodes, can be fabricated by controlling only one dimension of the structure on the atomic scale—usually the direction of crystal growth. To produce single-electron transistors that work at temperatures far above the temperature of liquid helium, it is desirable to control the structure of the device atom by atom in all three dimensions.

NANOSTRUCTURE FABRICATION. Nanometer-scale control is currently being achieved in exploratory research using electron microscopes. Nanostructures that show quantization in all directions, so-called quantum dots, have been made by many groups, including those led by Mark Reed, professor of electrical engineering at Yale University, New Haven, Conn.; Harold Craighead and his co-workers at the National Nanofabrication Facility at Cornell University, Ithaca, N.Y.; and many other laboratories in Europe, Japan, and the United States. While most of the structures that can be fabricated are of the order of a hundred or at least several tens of nanometers, recent developments in scanning tunneling microscopy have shown the possibility of moving around single atoms.

> Mesoscopic systems resemble waveguides—except their sizes can be changed in picoseconds

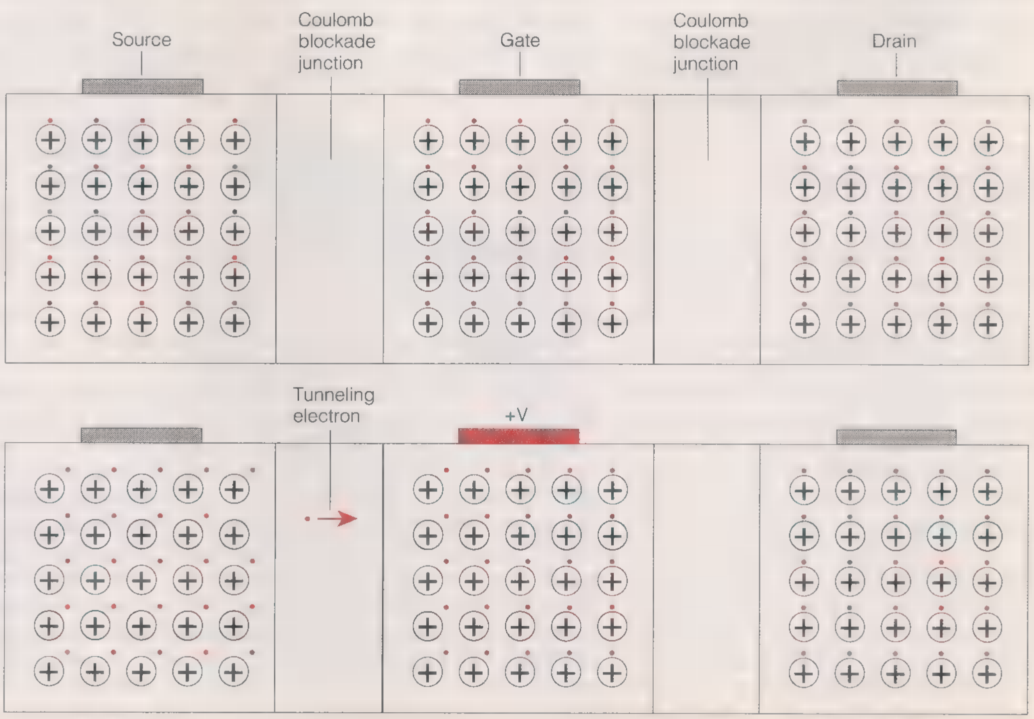
For purposes of observation, scanning tunneling microscopes have had a resolution close to 0.1 nm since their invention by Gerd Binning and Heinrich Rohrer at IBM's laboratories in Zurich ["Tools for probing 'atomic' action," by J.M. Gibson, *Spectrum*, December 1985, pp. 38–44]. Most recently, however, they may prove useful for structuring the surfaces of silicon devices on a scale smaller than a nanometer. For features larger than 20 nm, the more conventional means of lithography (electron beam, X-ray, and the like) are expected to be effective.

In a scanning tunneling microscope, a tip (typically made from tungsten) can be moved distances of tens of nanometers by piezoelectrically altering the length of a crystal by adjusting an applied voltage. Electrons tunnel from the tip to the surface under investigation. The tunneling current between the tip and the surface can be kept constant by moving the tip vertically under feedback control. Since tunneling depends exponentially on the distance from the conducting surface, the surface can then be mapped out by registering the distance of the tip (voltage on the piezoelectric crystal) that keeps the tunneling current constant.

The scanning tunneling microscope also can be used to expose a photoresist, as shown by Mark McCord, research staff member at IBM in Yorktown Heights, and Christie Marrian and Richard Colton at the Naval Research Laboratory in Washington, D.C., among others. The tip also can be used to scratch the surface mechanically or—with the aid of large tunneling currents—electrically [Fig. 7].

ENGINEERING CHALLENGES. From an engineering applications viewpoint, however, questions of throughput, mass production, and economic power give pause. Other difficulties include the extension of the effects to operation at room temperature.

All the same, all the elements are in place to explore the possibility of nanometer- or molecular-sized electronic circuits. Struc-



[6] Two horizontal Coulomb blockade tunnel junctions in series create a single-electron transistor. The center gate capacitor between the two Coulomb blockade junctions determines the polarization charge. When there is no polarization charge, no current can flow through the tunnel junctions [top]. When a positive voltage is applied to create a polarization charge, electrons can tunnel one by one [bottom]. The voltage on the drain will affect whether or not electrons can tunnel through the second Coulomb blockade junction; here they are shown not doing so. Such a single-electron transistor has been experimentally confirmed by several groups.

Joseph Lyding and John R. Tucker, University of Illinois; Ted K. Higman, University of Minnesota

[7] Stripes 40 to 80 nanometers wide were scribed on the source of a silicon metal-oxide-semiconductor field-effect transistor to demonstrate that such narrow features could be fabricated, and that they would produce quantum interference effects. The stripes were made early this year at the University of Illinois using a scanning tunneling microscope.

tures can be made on a nanometer scale and single-electron transistors can be integrated. Many other physical phenomena on this scale also may be useful if translated into device function.

There are formidable obstacles to overcome. The known methods of lithography cannot be extended to 1-nm feature sizes. The scanning tunneling microscope, which can fabricate such feature sizes, is not known for its speed: at the current rates of engraving, 1 bit would take milliseconds, resulting in days just for the *Encyclopaedia Britannica*. If we started now on the Library of Congress, we might not be entirely finished with one chip for another 30 years. Even so, we could start and actually expect to finish.

Another obstacle is that "single electronics" works now only at extremely low temperatures, best at millikelvins. Thus miniature refrigeration systems may indeed become a necessary evil.

Then, too, there are fundamental limitations to device speed. Science has led to femtosecond spectroscopy. To put this time scale in perspective, light propagates only 300 nm in free space in 1 femtosecond. One therefore can imagine that communication on a chip, even if improved by sophisticated optoelectronic circuits, will not approach the femtosecond barrier easily.

Picoseconds (and corresponding terahertz frequencies), however, can be reached. In fact, picoseconds represent a natural switching speed on the mesoscale, as proven by resonant tunneling diodes. A typical time constant obtained from the solving of Schrödinger's equation is in the range of 0.5 ps for device features in the range of 10 nm, and that half-picosecond constant, moreover, scales approximately linearly with distance.

Electronics can approach far larger densities. Physical mechanisms such as single-electron switching and mechanical control over single atoms have been found. They will form the basis of further technological development.

To be sure, many obstacles still need to be overcome, including the enormous cost of research and development. These obstacles work for the pessimists who warn us that we should be content to further develop conventional bipolar and FET technology instead of looking for drastic change.

For them we would like to finish by quoting Jack Morton, former vice president of Research at Bell Laboratories, writing in his article "From Physics to Function" in the September 1965 issue of *IEEE Spectrum*: "An industry does not have to be analogous to a single individual or family [referring to the existing technology] in its morphological development. It can be a dynasty spanning many generations—if it has the good fortune or good sense to seek repeated renewal. . .through repeated trips back to the 'fountain of youth' of basic science. It must consciously seek to translate basic science into new technology that is economically more powerful than the old."

TO PROBE FURTHER. Overviews and comprehensive reviews of many new developments in nanometer-scale structures and mesoscopic systems are given in *Granular Nanoelectronics*, edited by David K. Ferry, John R. Barker, and Carlo Jacoboni, Plenum Press, New York and London, 1990.

Many basic physics concepts in nanostructure science are described in *Solid State Physics*, Vol. 44, edited by H. Ehrenreich and D. Turnbull, Academic Press, Boston, San Diego, and New York, 1991. In particular, see the section "Quantum Transport in Semiconductor Nanostructures," by C.W.J. Beenakker and H. van Houton, pp. 1–228.

Volume 32 of the 1988 *IBM Journal of Research and Development* is dedicated to the subject of mesoscopic systems and devices. It also contains a review of correlated single electron transfer by Konstantin K. Likharev. Likharev and Tord Claeson have reviewed the background and principles of the single-electron transistor in "Single Electronics," *Scientific American*, June 1992, pp. 80–85.

ACKNOWLEDGMENTS. Some of the ideas we present have been influenced by keynotes delivered at a recent workshop by Markus Büttiker and Trey Smith, IBM Corp., Yorktown Heights, N.Y.; Konstantin K. Likharev, State University of New York at Stony Brook, N.Y.; and Gregory Timp, AT&T Bell Laboratories, Murray Hill, N.J., and discussions with Raymond Ashori of AT&T Bell Laboratories at Murray Hill. Karl Hess acknowledges the support of the U.S. Army Research Office and the U.S. Office of Naval Research.

ABOUT THE AUTHORS. Karl Hess (F) is professor of electrical and computer engineering at the University of Illinois in Urbana. He is also research professor in the university's Beckman Institute for Advanced Science and Technology and co-directs the National Science Foundation's Center for Computational Electronics.

Gerald J. Iafrate (SM) is the director of the U.S. Army Research Office, Research Triangle Park, N.C., where he researches solid-state physics and quantum transport. ◆

Good-bye to TV ghosts

A broadcast ghost-canceling reference signal will enable digital signal-processing circuits in TV sets to erase multipath distortions

From the early days of television, ghosts have bothered viewers. For ■ good part of that time, engineers have known how to expel the uninvited guests. But only recently have circuit costs shown signs of dropping low enough for ghost-canceling circuits to become practical for the home television receiver.

Possibly as soon as late August, members of the Advanced Television Systems Committee in Washington, D.C., will select a ghost-canceling reference (GCR) signal as a voluntary U.S. standard. The signal will be embedded in the vertical blanking interval of the transmitted National Television System Committee (NTSC) video signal and will undergo the same distortions as the video signal. Television receivers equipped with special digital signal processors will compare the received GCR signal with an unimpaired stored GCR waveform. The circuits in the receiver will then automatically configure one or more compensatory filters to correct for the distortions introduced in the transmission path.

To do this, a ghost-canceling system in a television receiver requires a channel identifier and ghost-canceling filters. The identifier uses the received GCR signal to calculate the channel impulse response (the characteristics of the impaired channel). To obtain an accurate and rapid estimate of the channel response for a wide range of ghosts, it is desirable that the energy content of the GCR signal be as high as possible. The signal that defines the channel response is used to calculate the deghosting filter tap coefficients.

Japan already has ■ GCR signal standard. One devised by the Broadcast Technology Association (BTA) of Japan was standardized there in 1989 and television broadcasters in Japan now transmit the association's GCR signal. But in order to benefit from it, consumers have had to purchase set-top converters that defeat or limit the use of high-end receiver functions like picture-in-picture. And the complexity of connecting set-top converters, television receivers, and videocassette recorders daunts many consumers. But now at least one Japanese television manufacturer is incorporating ghost-canceling circuits in ■ television set.

Ronald K. Jurgen Contributing Editor

The National Association of Broadcasters (NAB) in Washington, D.C., was aware of the developments in Japan. It also realized that digital signal processors were becoming cost-effective for television receivers. So in 1989 it requested the Advanced Television Systems Committee (ATSC) to examine various ghost-canceling techniques with ■ view to system testing and hence to defining a single GCR signal standard for NTSC broadcasts in the United States. Then in July 1990, NAB released a request for proposal for ghost-canceling systems for the association to consider for adoption as ■ voluntary U.S. broadcasting standard.

As the Philips and Sarnoff/Thomson systems each won, but on disparate tests, a hybrid will use the best of both

Progress was rapid. In response to NAB's request, ATSC formed ■ specialist group on ghost canceling (T3S5). Five systems proposed by BTA, AT&T/Zenith Electronics Corp., David Sarnoff Research Center/Thomson Consumer Electronics, Philips Laboratories, and Samsung Electronics were tested and evaluated by T3S5 (details later). Based on extensive testing of prototype hardware and evaluation of written submissions by the proponents, T3S5 concluded that the Philips and Sarnoff/Thomson GCR signals should become the focus of final deliberations in T3, ATSC's technology group on distribution. Then a letter sent on April 7 to ATSC by Philips and Sarnoff/Thomson proposed ■ hybrid GCR signal incorporating features of both their systems.

On April 23, T3S5 agreed to review the new Sarnoff-Philips proposal and plans for a fast-track evaluation program were made: laboratory and field tests comparing the original Philips signal with the original Sarnoff/Thomson signal were expected to have been completed by T3S5 and ■ recommendation formulated for T3 by the end of June. That report would then be submitted to the full ATSC membership for a mail vote, with responses due within 60 days. If two-thirds of the voting members elect to support the recommendation, the United States will have a voluntary ghost-canceling standard.

PRE- AND POST-ECHOES. A typical ghost-canceling system was described by Stephen Herman, ■ staff member at Philips Laboratories, Briarcliff Manor, N.Y., in ■ paper presented at the NAB Convention in Las Vegas, Nev., in April 1992. When several versions of the transmitted signal are received, he said, the strongest one is usually selected as the main signal. Signals that arrive before and after the strongest one are called pre- and post-echoes, respectively. Post-echoes occur when the transmitted signal is delayed by reflections from buildings, trees, and the like. Pre-echoes sometimes occur, Herman explained, through direct pick-up in an inadequately shielded television receiver, when ■ weak signal is received over the air before the delayed main signal is received over a cable system, for example.

Post-echoes, Herman said, can be canceled with an infinite impulse response (IIR) digital filter whereas pre-echoes and close-in post-echoes are usually canceled with a finite impulse response (FIR) digital filter.

The impaired composite video baseband input signal is first digitized [Fig. 1] and then

Defining terms

Bessel-type pulse: a sinusoidal frequency sweep from dc to 4.2 MHz.

Equalization: the act of adjusting a waveform or spectrum into ■ desired shape.

IRE standard scale: a linear scale for measuring, in arbitrary IRE units, the relative amplitudes of the various components of a television signal.

Vertical blanking interval: an interval in a television signal when the source output is blanked during the vertical rescan time.

Vertical interval reference: a signal used as a reference for use in resetting black level, white-to-black gain, burst amplitude, and phase to correspond to program chrominance.

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the ghosted GCR signal is extracted from it. Using a comparison of the ghosted GCR signal and the known GCR waveform, Herman explained, an algorithm calculates the coefficients of the digital filters needed to cancel the echoes. The calculations are done with digital signal-processor chips. The filters can be implemented with very large-scale ICs optimized for this application. The digital-to-analog converter then restores the digital signal to an analog video form.

It should be noted that a GCR signal standard applies only to the GCR signal that is transmitted. Television set manufacturers may use any method they wish to process the signal. For high-end receivers, for example, they may well opt for more sophisticated circuits and settle for a simpler and less costly approach for low-end models.

WHICH VBI LINE? Another important aspect of the ghost-canceling standard is agreement on a specific vertical blanking interval (VBI) line the GCR signal would be placed on.

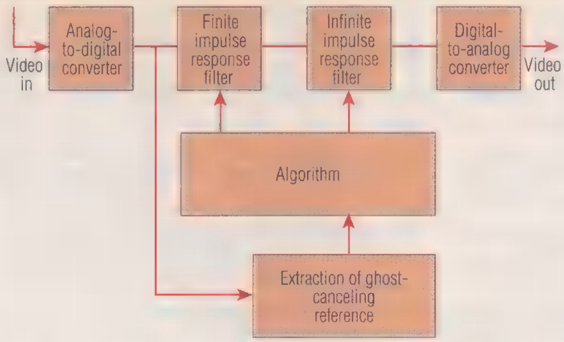
In a report on GCR signals released by ATSC on March 20, it was stated that broadcasters have been studying the replacement of the line 19 vertical interval reference (VIR) color pulse with the GCR training signal. The report stated further that there are currently very few television receivers in the United States that use the VIR pulse. VIR-equipped television receivers have not been manufactured for several years.

Lynn Claudy, NAB's director of advanced engineering and technology, told *IEEE Spectrum* in his Washington office that the ATSC planned to petition the Federal Communications Commission (FCC) in Washington, D.C., for rule-making in regard to using line 19 for a GCR signal. It might take the FCC six months to a year to make a decision, Claudy said, but in the meantime ATSC would also request that the FCC grant a "blanket waiver" for GCR signals, allowing broadcasters to turn off the VIR pulse and replace it with the GCR signal while the petition was being considered at the FCC.

The additional cost of generating the GCR signal will depend on the equipment available at the television station to insert signals in the VBI. In the case of one manufacturer's digital signal generator, Claudy told us, television broadcasters would be able to buy an inexpensive (about US $250) plug-in programmable ROM to provide the GCR signal.

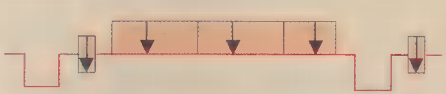
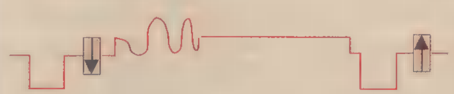
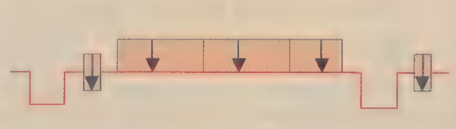
BIRTH OF A HYBRID. The NAB field tests of the five proponent GCR systems took place in the Washington, D.C., area from September through November 1991. One low-band very high-frequency station (channel 4) and two ultrahigh-frequency stations (channels 20 and 50) participated. Measurements were made at 106 locations, of which 70 percent or so received strong signals and the rest, weak signals.

Trained observers evaluated the impairment of the television images due to multipath distortion before and after ghost cancellation on a five-point subjective assess-



[1] An echo- or ghost-canceling system uses an algorithm to calculate the coefficients of the digital filters needed to cancel the ghosts.

[2] Arrows indicate the color burst phase of waveforms for the proposed hybrid ghost-canceling system. Plus and minus signs refer to the polarity of the Bessel-type pulse and pseudo-noise sequence.

Waveform	Eight-field superframe			
	Field	Color frame	Signal	Polarity
	f_1	1	Pseudo-noise	+
	f_2	2	Bessel-type	+
	f_3	3	Bessel-type	–
	f_4	4	Pseudo-noise	+
	f_5	1	Pseudo-noise	–
	f_6	2	Bessel-type	–
	f_7	3	Bessel-type	+
	f_8	4	Pseudo-noise	–

ment scale from the International Radio Consultative Committee (CCIR).

In the same year, Cable Television Laboratories (CableLabs), Boulder, Colo.—an R&D consortium of cable television operators in the United States and Canada—ran tests to compare the effectiveness of the five proposed GCR signals in the context of cable systems. Laboratory tests were conducted on the CableLabs test bed in Alexandria, Va., in November. Field tests were conducted in November and December to measure the GCR performance from the cable headend (where ghost cancelers are most effective) to a set-top converter's output.

When NAB reported in February on the results of its field tests, its news release stated that "one system, developed by Philips Laboratories, appears to be the superior performer." The report itself stated that "The Philips system consistently outperformed the other four systems."

But in March, when CableLabs released the results of its field and laboratory tests, its report said that, based on objective measurements, "The Sarnoff/Thomson ghost canceling system tested by CableLabs consistently outperformed all other proposed systems in the laboratory and in the field. In the majority of conditions tested, the Sarnoff/Thomson system achieved a better equalization of the video channel, and a more complete removal of visible ghosting artifacts in the picture."

DURABLE GHOSTS. How could the test results differ so? We asked that question of Craig K. Tanner, vice president, advanced television projects, for CableLabs. He told us that the CableLabs tests concentrated on ghosts of short duration, unlike the NAB tests, which tested for long ghost correction. Tanner emphasized that in cable systems, long ghosts are not a problem, whereas short ghosts are.

It was after those tests that the ATSC announced that only the Philips and Sarnoff/Thomson systems would be considered further for use as a GCR standard. Then, on April 7, came the joint letter to committee chairman James C. McKinney, in which a hybrid of the two systems was proposed by Michael Isnardi, head of systems research for Sarnoff in Princeton, N.J., and C.A.A.J. Greebe, scientific advisor to Philips in Briarcliff Manor, N.Y.

As to why the hybrid proposal was forthcoming, *Spectrum* asked J. Peter Bingham, president of Philips Laboratories, and James E. Carnes, president and chief operating officer of the David Sarnoff Research Center, and not surprisingly got similar answers. Bingham told us that Philips and Sarnoff/Thomson wanted to "combine forces to give the best of what NAB liked and the best of what CableLabs liked" and to have a system that "meets everybody's criteria better than either the Philips or Sarnoff/Thomson systems did alone."

Carnes emphasized to us that the Philips system was better for noisy long ghosts and the Sarnoff/Thomson system excelled for close-in or short ghosts. "We decided to use parts of both systems to have the best of both worlds and to satisfy both NAB and CableLabs," he said. Both Bingham and Carnes agreed that their partnership on high-definition television (HDTV), as members of the Advanced Television Research Consortium, made it easier for the two organizations to combine forces once again on the hybrid system.

'Ghosting effects' with HDTV will manifest themselves in other ways, including total loss of picture

The proposed hybrid GCR is a composite of the Philips and Sarnoff/Thomson proposals. In a report to the ATSC on April 23, Sarnoff's Charles Dieterich and Michael Isnardi and Philip's C.A.A.J. Greebe said that the compromise results in a system "which can provide the high performance and efficient algorithmic methods required for cable head-ends as well as for low-cost home receivers."

The hybrid GCR [Fig. 2] is an eight-field sequence consisting of two main signal types: a thrice-repeated pseudo-noise sequence, as in the original Sarnoff/Thomson proposal, and a Bessel-type pulse, as in the original Philips proposal.

The pseudo-noise sequence is said to be well suited for efficient equalization and cancelation of short-delay ghosts. The sequence, which lasts for about 52 microseconds, resides on a 36-IRE pedestal [see Defining terms]. The amplitude range at luminance frequencies below 2 MHz is approximately 0–70 IRE.

The Bessel-type pulse may be either short (18 μs) or long (35 μs). If a broadcaster wishes to use a short pulse, there is no constraint on signal content on the following vertical blanking interval line. For example, "bursted" data signals that are present for only one field or that vary from field to field can be used. If the long option is used, however, further evaluation and testing is required of the effect the data on the following VBI line has on the ghost cancellation process, as well as the effect on that data of the delayed GCR.

The selection of a short or long Bessel-type pulse by a broadcaster would be determined largely by the terrain and surface clutter in the broadcast area. Enough energy for substantial ghost reduction can be provided from either pulse, but the greater energy (more than 5 dB) of the long pulse relative to the short one characterizes the ghosting effect more accurately and ensures higher accuracy when noise is present.

In the eight-field pattern, the polarity and sequence of waveforms are such that successive fields with the same signal type [fields F_2 and F_3 in Fig. 2, for example] can be subtracted to leave an amplified version of the signal without sync, burst, and their ghosts so that there can be an average of 7.5 updates per second.

WHAT ABOUT HDTV? Ghost canceling certainly can improve picture quality for home viewing of NTSC transmissions, but HDTV is another matter. Robert Hopkins, executive director of ATSC, told *Spectrum* that with HDTV ghost canceling will be even more important. Four of the five systems being tested for a U.S. terrestrial transmission standard for HDTV are digital, he noted. With digital signals there is no ghosting *per se*, because they are not coherent signals, Hopkins said. While there still will be "ghosting" effects, they will manifest themselves in other ways, including total loss of the picture.

Once a GCR standard is set, broadcasters will begin to transmit the GCR signal (always assuming that the FCC has given a blanket waiver to use vertical blanking interval, line 19) and cable operators will be able to use ghost-canceling equipment in the headends of their systems.

Insofar as television receiver circuitry is concerned, Amihai Miron, television systems director for Philips, told us in Briarcliff Manor, N.Y., that the goal for such circuits is to make them approximately equal in manufacturing cost to picture-in-picture circuits. Philips expects to have television receivers with ghost-canceling circuits on the market as soon as early 1994.

TO PROBE FURTHER. Four reports summarize the testing of proposed systems in the United States and analyze those tests.

- For availability of "Field tests of ghost canceling systems for NTSC television broadcasting," Jan. 31, 1992, contact the National Association of Broadcasters, 1771 N. St., N.W., Washington, D.C. 20036; 202-429-5346.
- For availability of "Ghost canceling reference signals," March 20, 1992, contact the Advanced Television Systems Committee (ATSC), 1776 K St., N.W., Washington, D.C. 10006; 202-828-3130.
- "Field and laboratory tests of NTSC ghost canceling systems," March 10, 1992, is available from Cable Television Laboratories, 1050 Walnut St., Suite 500, Boulder, Colo. 80302; 303-939-8500.
- "Computer simulations and laboratory tests of proposed ghost-canceling system," March 1992, has been prepared by the Communications Research Centre, Department of Communications, Ottawa, Ont., Canada. For a copy, contact ATSC at the above address.

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1992 Major Medalists

The IEEE honors 10 outstanding contributors

IEEE Edison Medal
G. David Forney Jr.

G. David Forney Jr. (F), vice president of technical staff, Motorola Codex Corp., Motorola Inc., Mansfield, Mass., has received the Edison Medal "for original contributions to coding, modulation, data communication modems, and for industrial and research leadership in communications technology."

In 1970–71 Forney was the principal designer of a family of high-speed telephone-line data modems, including the first commercially successful 9600-b/s modem. Named vice president of R&D for Codex in 1975, Forney oversaw the further development of its data communications product line. He held various managerial positions until 1986, when he assumed his present position.

In recent years he has been working on the fundamental theory of trellis-coded modulation, while contributing to increasing commercial telephone-line modem speeds to 19.2 kb/s and beyond.

Sunny Yellen

IEEE Medal of Honor
Amos E. Joel Jr.

Amos E. Joel Jr. (LF) has received the IEEE's 1992 Medal of Honor "for fundamental contributions to and leadership in telecommunications switching systems." The award, as well as the IEEE major medals to nine honorees, were presented at the IEEE Honors Ceremonies in Boston on May 10.

Currently a consultant in South Orange, N.J., Joel spent most of his professional career with Bell Telephone Laboratories (1940–83). A pioneer in the development of electronic switching, he used the fundamental engineering studies he began in 1948 as the basis for the switching systems he later designed. He supervised planning for the Bell System's first electronic telephone switching systems and played a major role in establishing the concepts of electronic switching now employed throughout the world. More than 70 U.S. patents have been issued for his work, including a basic patent for the switching aspects of cellular mobile radio.

During World War II, Joel designed early general-purpose digital computers and cryptanalysis machines. Following the war, he conceived and taught the first course on switching systems and circuit design and went on to design the first automatic telephone billing equipment.

Active since his student days in the IEEE and its predecessor, the American Institute of Electrical Engineers, Joel has served on many committees and boards. He was also chairman of the New York Section and president of the Communications Society. He was awarded the IEEE Alexander Graham Bell Medal in 1976 and is a member of the National Academy of Engineering.

IEEE Lamme Medal
Dietrich R. Lambrecht

Dietrich R. Lambrecht (F), retired, formerly executive director, Power Generation Group, Kraftwerk Union (KWU), Siemens AG, Mülheim an der Ruhr, Germany, has been awarded the Lamme Medal "for outstanding contributions to the advancement of turbine-generator engineering and technology, particularly superconducting rotor winding."

Lambrecht became manager of KWU's generator development department in 1969 where he was responsible for developing fully water-cooled power station generators of up to 1640 MVA. During this work, he discovered and investigated the problem of the torsional impact of electric transients on turbine and generator shafts.

When Siemens KWU undertook to develop generators with a superconducting field winding in 1978, Lambrecht was made project manager of a program to design and manufacture a generator with a frame size of 400 MVA, which is now in the final stage of production.

IEEE Founders Medal
Roland W. Schmitt

Roland W. Schmitt (F), president, Rensselaer Polytechnic Institute, Troy, N.Y., has been awarded the Founders Medal "for leadership in addressing competitiveness challenges, and for outstanding contributions to technology transfer."

Schmitt was previously a senior vice president for science and technology for General Electric Co. and a member of GE's Corporate Executive Council. From 1978 to 1986 he directed the GE Research and Development Center in Schenectady, N.Y., one of the world's largest and most diversified industrial laboratories.

He is a member and past chairman (1984–88) of the National Science Board, the policy-making body of the National Science Foundation. He also chairs the Council on Research and Technology and the U.S. Office of Technology Assessment's advisory panel on American Industry and the Environment: Issues for Trade and Competitiveness.

IEEE Education Medal
Ronald W. Schafer

Ronald W. Schafer (F), institute professor and John O. McCarty chair, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, Ga., has been awarded the Education Medal "for excellence in curriculum development, teaching, and textbooks in digital signal processing and digital speech processing."

From 1968 to 1974 Schafer was a member of the technical staff and a supervisor at Bell Laboratories, Murray Hill, N.J., where he was engaged in research on speech processing and digital signal processing. He and Lawrence R. Rabiner later wrote the textbook *Digital Processing of Speech Signals*. He joined the faculty of Georgia Tech in 1974, where his work has focused on digital signal processing and digital speech processing.

A text he coauthored with Alan V. Oppenheimer while he was still with Bell Labs, *Digital Signal Processing*, was published in 1975 and became the most widely used textbook in its field.

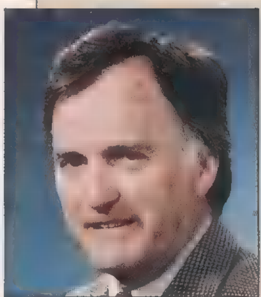
IEEE Richard W. Hamming Medal
Lotfi A. Zadeh

Lotfi A. Zadeh (LF), professor emeritus, department of electrical engineering and computer science and director of The Berkeley Initiative in Software Engineering, University of California at Berkeley, has received the Richard W. Hamming Medal "for seminal contributions to information science and systems, including the conceptualization of fuzzy sets."

Zadeh was a member of the electrical engineering department at Columbia University from 1946 to 1959, where much of his work centered on the development of systems theory and the management of uncertainty in systems analysis. He joined the University of California at Berkeley in 1959.

In 1965, he published his seminal paper on fuzzy sets. This paper laid the foundation for what has become a wide-ranging theory with a broad spectrum of applications extending from consumer products and industrial systems to medical diagnosis and securities trading.

IEEE Medal for Engineering Excellence
Charles Elachi



Charles Elachi (F), senior research scientist and assistant laboratory director for space science and instruments at the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, has been awarded the IEEE Medal for Engineering Excellence "for the development, demonstration, and application of synthetic aperture radar for remote mapping of planets."

In his 20 years at JPL, Elachi has played a leading role in developing the field of spaceborne imaging radar. His work for the National Aeronautics and Space Administration (NASA) has dealt with such fields as comparative imaging radar planetology, earth imaging radar geology, and more recently, the Shuttle Imaging Radar Series.

He has authored over 200 publications on active microwave remote sensing, wave propagation and scattering, electromagnetic theory, lasers, and integrated optics, and has written two remote sensing textbooks.

IEEE Heinrich Hertz Medal
James R. Wait

James R. Wait (LF), emeritus Regents' Professor, University of Arizona, Tucson, has been awarded the Heinrich Hertz Medal "for fundamental contributions to electromagnetic theory, to the study of propagation of Hertzian waves through the atmosphere, ionosphere and the earth, and to their applications in communications, navigation and geophysical exploration." At the U.S. Department of Commerce Laboratories, Boulder, Colo., Wait led efforts that set the foundation for the mode theory of earth-ionosphere propagation of electromagnetic waves at very low frequencies. This theory became the cornerstone for the design of global communications systems at these frequencies. He joined the University of Arizona in 1980. His current interests as a consultant in electromagnetics are in the application of electric transients to subsurface probing of the earth and related inverse problems.

IEEE Alexander Graham Bell Medal
James L. Massey

James L. Massey (F), professor of digital systems engineering, Swiss Federal Technical University, Zurich, is the recipient of the Alexander Graham Bell Medal "for contributions to the theory and practical implementation of forward-error-correcting codes, multi-user communications, and cryptographic systems; and for excellence in engineering education."

Massey joined the faculty at the University of Notre Dame, Indiana, in 1961, where he remained until 1977. Much of his research there was supported by NASA's Goddard Space Flight Center and led to such innovations as the "quick-look-in" convolutional codes—still used in deep-space systems with sequential decoding—and the optimum frame synchronization technique.

He assumed his present position in 1980. Since that time his major research has been in cryptographic systems, leading to several patents and the formation in 1984 of Cylink Corp., Sunnyvale, Calif.

IEEE John von Neumann Medal
C. Gordon Bell

C. Gordon Bell (F), a computer industry consultant in Los Altos, Calif., and Boston, is the recipient of the John von Neumann Medal "for innovative contributions to computer architecture and design."

Bell joined Digital Equipment Corp. in 1960 and was responsible for DEC's first minicomputers and timesharing computer. His tenure at DEC was interrupted for a six-year term (1966–72) at Carnegie Mellon University, Pittsburgh, as a professor of electrical engineering and computer science. On his return to DEC as vice president of R&D, he led the development of the company's VAX and VAX Computing Environment, introduced in 1980.

He left DEC in 1983 to cofound Encore Computer Corp., which produced one of the first multiple-microprocessor machines, and later Ardent Computer, which built the first graphics supercomputer. He is a founder and director of the Computer Museum in Boston.

Forum

(Continued from p. 6)

Ethical theory and practice

Donald Christiansen's editorial in April [p. 19] was most interesting. As I see it, "The ethics of argument" is beyond the bounds of pure engineering.

Argument, politics, creativity, and other human disciplines and traits are a part of "management" and form the glue that makes engineering projects succeed or fail in the real world. Pure "ivory tower" engineering is based on physical forces, which appear to hold within the time and space of our experience. These forces are investigated, put into practice, and best understood by the imperfect field of mathematical approximations, under the corrective of constant revision.

It is therefore not surprising to note that engineering managers are subject to human problems—probably more so since early training and interests deal in the main with physical experiments and mathematics, which techniques cannot be applied to disciplines governed by human laws and shortcomings. Only the rare individual possesses both the ability to master many disciplines and the traits necessary to become an outstanding engineer.

David Scheets
Camarillo, Calif.

Birth of a satellite

I note that Beardsley Graham [April, p. 6] claims precedence for George O. Smith over Arthur C. Clarke with regard to communications satellites. I have in my possession a facsimile of a paper, "THE SPACE STATION—Its Radio Applications" by Clarke, dated May 25, 1945, which is autographed by him. I obtained it from the Intelsat booth at the Telecoms 79 Expo in Geneva, where I had the honor to meet Clarke. This paper was published in 1945 in the widely read British magazine *Wireless World*, so I assume that what I have is effectively a copy of the manuscript submitted to that magazine.

Evidently, while Smith may have been the first to describe such satellites in a work of fiction, precedence cannot be claimed on his behalf for the innovation itself. In fact, Clarke says in his paper that the space station was originally conceived as a refueling depot for ships leaving the earth. He went on to say that: ". . . Other uses, some of them rather fantastic, have been suggested for the space station, notably by Hermann Noordung . . ." (author of "Das Problem der Befahrung des Weltraums").

Adrian J. Morant
Edgware, Middlesex, England

Counter to Graham's claim that communications satellites were first described in George O. Smith's *Equilateral*, published in 1947, I cite the following excerpt from Arthur C. Clarke's *Profiles of the Future* (my copy, dated 1964):

> To the best of my knowledge, the use of artificial satellites to provide global TV was first proposed by myself in the October 1945 issue of the British radio journal *Wireless World*. The scheme then put forward, under the snappy title "Extraterrestrial Relays," envisaged the use of three satellites 22 000 miles above the equator. At this particular height, a satellite takes exactly twenty-four hours to complete one orbit, and thus stays fixed forever over the same spot on the Earth.

Roger Shimada
Roseville, Minn.

Smith's "Venus Equilateral" novelettes appeared in Street and Smith's *Astounding Stories* starting in the October 1942 issue and continuing for about three years. These stories were collected in a hardcover book by Prime Press in 1949, and Ballantine Books added the one later story to its paperback edition, called *The Complete Venus Equilateral*, in 1976. The Ballantine edition had an introduction by Arthur C. Clarke, in which he tells how Willy Ley mailed him monthly copies of *Astounding* during the war.

Clarke says he read the Venus Equilateral stories as they came out, and John Pierce suggested to him that they were in his subconscious when he wrote his famous *Wireless World* paper in 1945. Smith, however, told it to me somewhat differently in the one conversation I had with him. He said that Clarke was so annoyed at the orbital location of the Venus Equilateral Relay Station (a Trojan position in Venus orbit for relaying radio signals around the Sun) that he came up with the geostationary satellite position as a direct response.

The actual question is probably this: do creative people really have any notion where their ideas come from? I think not. My guess is that many are still living out long-forgotten stories they read in *Astounding*.

Lee Goeller
Haddonfield, N.J.

Human intelligence

Profiles of distinguished contributors to information science (like the profile of Claude E. Shannon [April, p. 72]) suggest that these great scientists are committed to the idea that machines can think: "You bet. I'm a machine and you're a machine, and we both think, don't we?"

Granted that human intelligence is a "machine" phenomenon (which, after all, is the only position that science can take), the crucial open issue is how human intelligence got to be programmed, that is, "How was the software created?"

Many scientists, Gödel and Turing among others, have clearly demonstrated that complex automata can have characteristics that cannot be elucidated by formal logical methods. It is my humble view that the deeper characteristics of the human mind—such as self-awareness, emotions, creativity, and free will—are properties of complex automata that lie in regions inaccessible to logical understanding.

A theological explanation of such characteristics also breaks down, because, in my opinion, even a Supreme Being would not be exempt from the laws of mathematics and logic that preclude the programming of human intelligence.

This leaves the all-powerful stochastic powers of evolution as the only possible fountainhead of human intelligence. Members of the Search for Extraterrestrial Intelligence community are correct in their fundamental assumption that human intelligence is an evolutionary phenomenon, but I suspect that they are naive in assuming that this wondrous process could have occurred more than once in our galaxy, or even in our entire cosmos. This means to me that a deep understanding of human intelligence will forever elude us.

Henry Hurwitz Jr.
Schenectady, N.Y.

Corrections

The profile of Masaru Ibuka [December, pp. 27–28] should not have credited him with the invention of the transistor radio.

In the article "CCDing in the dark" [May, p. 30], all references to the M-1A1 tank should be to the M-1A2.

In Fig. 2 of the article "Grounds for signal referencing" [June, pp. 42–44], the line and neutral wires should be connected to the isolated-ground receptacle's short and long slots, respectively. The yellow isolated-ground wire should be connected to a separate rounded slot, not pointing to the neutral line. In Fig. 3, center, there should be a bond between neutral and ground on the secondary (right) side of the isolation transformer. —*Ed.*

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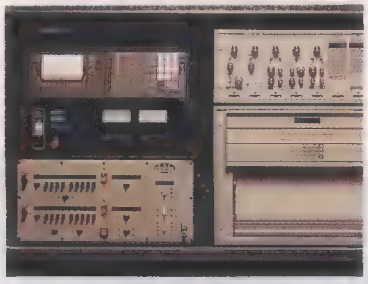

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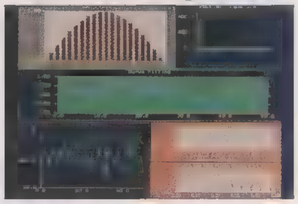

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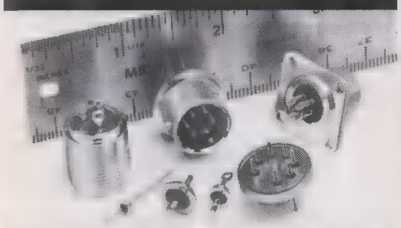

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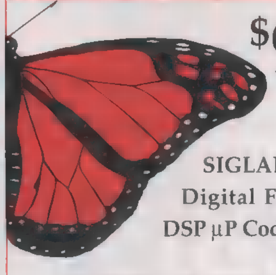

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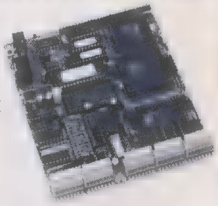

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The Electronics Department of Argonne National Laboratory is seeking an instrumentation engineer to participate in the development of x-ray detector systems based upon charge-coupled devices (CCD's) to be used for research at synchrotron light sources. A degree in electronics engineering, physics, or a related discipline and several years of relevant experience is required. Applicants should have experience in applications of scientific CCD's, in the use and design of opto-electronic imaging systems as well as in the design of analog and digital circuits and radiation detectors. Experience with data handling and computer systems is highly desirable. Argonne National Laboratory, one of the nation's major research centers, is located near Chicago and operated by the University of Chicago for the U.S. Department of Energy. Send resume in confidence to: Box EL-96552-33, ARGONNE NATIONAL LABORATORY, 9700 South Cass Avenue, Argonne, IL 60439.

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CHAIR, ELECTRICAL ENGINEERING

The Duke University School of Engineering invites applications for the position of Chair of the Department of Electrical Engineering. The Chair is responsible for the faculty, teaching programs, and research activities of the department, and reports to the Dean of the School. Eligibility for appointment as a full professor at Duke, with the academic credentials thereby required, is essential.

Interested persons should write to the **Search Committee for the EE Chair, Office of the Dean of the School of Engineering, 305 Teer Bldg., Duke University, Durham, NC 27706, including a complete curriculum vita and the names of four references. Applications should be received by August 1, 1992.**

Duke University

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Calendar

(Continued from p. 14J)

Suite 3, Altoona, Pa. 16602; 814-941-4666; fax, 814-941-4668.

Advanced Semiconductor Manufacturing Conference and Workshop (ED); Sept. 28–29; Cambridge Hyatt Regency Hotel, Cambridge, Mass.; Margaret Bachmeyer, SEMI, 2000 L St., N.W., Suite 200, Washington, D.C. 20036; 202-457-9584.

Petroleum and Chemical Industry Technical Conference (IA); Sept. 28–30; River City Marriott, San Antonio, Texas; Knox Pitzer, Thermon Manufacturing Co., 100 Thermon Dr., Box 609, San Marcos, Texas 78666; 512-396-5801; fax, 512-396-3627.

13th International Electronics Manufacturing Technology Symposium (CHMT); Sept. 28–30; Hyatt Regency Inner Harbor, Baltimore, Md.; Bill Moody, 2529 Eaton Rd., Wilmington, Del. 19810; 302-478-4143; fax, 302-478-7057.

Advanced Semiconductor Manufacturing Conference and Workshop (ED); Sept. 30–Oct.1; Cambridge Hyatt Regency Hotel, Cambridge, Mass.; Margaret Bachmeyer, SEMI, 2000 L St., N.W., Suite 200, Washington, D.C. 20036; 202-457-9584; fax, 202-659-8534.

Challenges in Optoelectronic Packaging (LEO, CHMT); Sept. 30–Oct.1; Hyatt Regency, Baltimore, Md.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

International Professional Communication Conference—IPCC '92 (PC); Sept. 30–Oct. 2; La Fonda on the Plaza, Santa Fe, N.M.; Susan Dressel, Information Services, Los Alamos National Laboratory, Mail Stop M704, Los Alamos, N.M. 87545; 505-667-6101; fax, 505-667-1754.

International Workshop on Hardware–Software Codesign (C, CAS); Sept. 30–Oct. 2; Holiday Inn, Estes Park, Colo.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Wash., D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

OCTOBER

GaAs Reliability Workshop (ED); Oct. 4; Fontainebleau Hilton Hotel, Miami Beach, Fla.; Anthony Immorlica, General Electric Co., Electronics Laboratory, Electronics Park, Syracuse, N.Y. 13221; 315-456-3514; fax, 315-456-0695.

Faculty Position in Manufacturing Engineering

Nominees and applicants are sought for a faculty position in the Department of Manufacturing Engineering at Boston University.

Areas of specialization in which we are seeking to expand include flexible automation and control, manufacturing design, manufacturing systems, and engineering materials, including composites and polymers. Other areas of specialization will be considered for exceptionally qualified candidates.

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Nominations and inquiries should be forwarded in confidence to:

Dr. Peter Z. Bulkeley, Chair
Department of Manufacturing Engineering
Boston University
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Boston, Massachusetts 02215

Nominations and applications will be accepted until the position is filled.

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Recent books

(Continued from p. 19)

Generic Cadd 5.0—Inside & Out. *Freeman, Ray C., III*, Osborne/McGraw-Hill, Berkeley, Calif., 1991, 540 pp., $24.95.

Pressure Sensors—Selection and Application. *Tandeske, Duane*, Marcel Dekker, New York, 1991, 312 pp., $89.75.

Understanding CLOS: The Common Lisp Object System. *Lawless, Jo A.*, and *Miller, Molly M.*, Digital Press, Bedford, Mass., 1991, 200 pp., $26.95.

Turbo Pascal 6 DiskTutor, 2nd edition. *Feibel, Werner*, Osborne/McGraw-Hill, Berkeley, Calif., 1991, 759 pp., $39.95.

Taking Software Design Seriously. *Karat, John*, Academic Press, San Diego, Calif., 1991, 368 pp., $44.50.

Electronic Circuits, Systems & Standards. *Hickman, Ian*, Butterworth-Heinemann, Stoneham, Mass., 1991, 220 pp., $32.95.

International Trends in Optics. *Goodman, Joseph W.*, Academic Press, San Diego, Calif., 1991, 525 pp., $64.95.

The Circuit Designer's Companion. *Williams, Tim*, Butterworth-Heinemann, Stoneham, Mass., 1991, 302 pp., $74.95.

Principles of Adaptive Optics. *Tyson, Robert K.*, Academic Press, San Diego, Calif., 1991, 298 pp., $49.95.

Ventura Publisher for Windows. *Berst, Jesse, et al.*, Microsoft Press, Redmond, Wash., 1991, 704 pp., $29.95.

Molecular & Cell Biophysics. *Nossal, Ralph*, and *Lecar, Harold*, Addison Wesley, Redwood City, Calif., 1991, 387 pp., $48.75.

Reflective Optics. *Korsch, Dietrich*, Academic Press, San Diego, Calif., 1991, 358 pp., $95.

The X Series Recommendations: Protocols for Data Communications Networks. *Black, Uyless*, McGraw-Hill, New York, 1991, 309 pp., $39.95.

Microsoft MS-DOS Programmer's Reference. *Microsoft*, Microsoft Press, Redmond, Wash., 1991, 472 pp., $24.95.

The Concise Dictionary of Management. *Statt, David A.*, Routledge, New York, 1991, 163 pp., $12.95.

How to Manage the R&D Staff: A Looking-Glass World. *Tingstad, James E.*, Amacom, New York, 1991, 290 pp., $55.

Advances in Languages and Compilers for Parallel Processing. Eds. *Nicolau, Alexandru, et al.*, MIT Press, Cambridge, Mass., 1991, 467 pp., $40.

Topics in Information Systems: On Object-Oriented Database Systems. Eds. *Dittrich, K.R., et al.*, Springer-Verlag, New York, 1991, 422 pp., $59.

Desktop Publishing by Design, 2nd edition. *Shushan, Ronnie*, and *Wright, Don*, Microsoft Press, Redmond, Wash., 1991, 424 pp., $29.95.

Microwave Semiconductor Devices. *Yngvesson, Sigfrid*, Kluwer Academic, Norwell, Mass., 1991, 471 pp., $65.

Local Area Networking. *Naugle, Matthew G.*, McGraw-Hill, New York, 1991, 279 pp., $34.95.

Microwave Integrated Circuits. Ed. *Konishi, Yoshihiro*, Marcel Dekker, New York, 1991, 632 pp., $150.

Electronics, Computers and Telephone Switching, Vol. 13. *Chapuis, Robert J.*, and *Joel,*

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Recent books

Amos E., Jr., North-Holland Publishing Co., New York, 1990, 428 pp., $90.

Open Systems Interconnection Handbook. Ed. *McClain, Gary R.*, McGraw-Hill, New York, 1991, 393 pp., $49.95.

Understanding Digital Troubleshooting, 3rd edition. *Cannon, Don L.*, SAMS/Macmillan Computer Publishing, Carmel, Ind., 1991, 286 pp., $24.95.

Advanced Microprocessors. *Tabak, Daniel*, McGraw-Hill, New York, 1991, 534 pp., $49.95.

Computer-Operated Systems Control. *Mahmoud, Magdi S.*, Marcel Dekker, New York, 1991, 680 pp., $150.

Advances in Computers, Vol. 32. Ed. *Yovits, Marshall C.*, Academic Press, San Diego, Calif., 1991, 331 pp., $69.95.

Neural Models and Algorithms for Digital Testing. *Chakradhar, Srimat T., et al.*, Kluwer Academic, Norwell, Mass., 1991, 184 pp., $58.

Analog Circuit Design. *Williams, Jim*, Butterworth-Heinemann, Stoneham, Mass., 1991, 389 pp., $44.95.

Powerpoint Presentations by Design. *Parker, Roger C.*, Microsoft Press, Redmond, Wash., 1991, 384 pp., $24.95.

Professional Workstations. *Wheeler, Thomas F.*, McGraw-Hill, New York, 1991, 279 pp., $42.50.

Op-Amp Circuits and Principles. *Berlin, Howard M.*, SAMS/Macmillan Computer Publishing, Carmel, Ind., 1991, 287 pp., $19.95.

Materials Handbook, 13th edition. *Brady, George S.*, and *Clauser, Henry R.*, McGraw-Hill, New York, 1991, 1056 pp., $74.50.

Electromagnetic Modelling and Measurements for Analysis and Synthesis Problems. Ed. *de Neumann, Bernard*, Kluwer Academic, Norwell, Mass., 1991, 447 pp., $144.

The New Telecommunications: Infrastructure for the Information Age. *Williams, Frederick*, Free Press/Macmillan, New York, 1991, 247 pp., $35.

Wire & Cable for Electronics: A User's Handbook. *Sclater, Neil*, McGraw-Hill, New York, 1991, 237 pp., $29.95.

Microsoft Word for Windows Revealed. *Tyson, Herbert L.*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 546 pp., $24.95.

Perturbation Techniques for Flexible Manipulators. *Fraser, Anthony R.*, and *Daniel, Ron W.*, Kluwer Academic, Norwell, Mass., 1991, 275 pp., $75.

Origins of the Modern Mind. *Donald, Merlin*, Harvard University Press, Cambridge, Mass., 1991, 413 pp., $27.95.

Build Your Own IBM Compatible and Save a Bundle. *Pilgrim, Aubrey*, Windcrest/McGraw-Hill, Blue Ridge Summit, Pa., 1991, 244 pp., $19.95.

Power Line Filter Design For Switched-Mode Power Supplies. *Nave, Mark J.*, Van Nostrand Reinhold, New York, 1991, 210 pp., $49.95.

The Edges of Science: Crossing the Boundary from Physics to Metaphysics. *Morris, Richard*, Simon & Schuster/Prentice-Hall, New York, 1990, 244 pp., $10.

Robotics Control and Society. Eds. *Moray, N., et al.*, Taylor and Francis, Bristol, Pa., 1990, 268 pp., $77.

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Staff Systems Engineer — Responsible for the development of system-level analog design concepts. Requires MSEE, strong background in high-speed analog circuit design, power distribution and grounding and signal processing, with a minimum of 8 years of progressively complex technical experience.*

Applied Research Manager — Conceive and plan projects involving assessment of system architecture, new technology trends, definition and selection of new concepts and approaches. Minimum of 10 years experience including 2 years in technical management. MS/Ph.D in Electrical Engineering or Physics, emphasizing ultrasound physics and signal processing.*

Staff and Sr. Scientists — Assume a key role in planning, organizing and conducting special ultrasound research projects. Minimum of 8 years experience for staff level and 5 years experience for senior level. MS/Ph.D in Electrical Engineering or Physics with emphasis in digital signal processing and image processing.*

Staff and Sr. Ultrasound Scientists — Plan and execute projects to develop new ultrasound technologies including 2D Imaging, Color Flow, Doppler, and Image/Display. Minimum of 8 years experience for staff level and 5 years experience for senior level. MS/Ph.D degree in Electrical Engineering or Physics with emphasis in digital signal processing and ultrasound physics.*

Staff Analog Design Engineer — Responsible for the specification, design, costing, and integration of high-speed analog circuitry, both discrete and integrated. Minimum of 8 years related experience including 4 years in high-speed analog designs, MSEE required.*

* Above positions require Ultrasound medical imaging experience.

Acoustic Physicist — New transducer development. Simulate, specify, evaluate and analyze trends and performance. Calibrate hydrophones and perform FDA measurements. Working knowledge of data acquisition and control using C and HP Basic required. Ph.D and 2 years experience.

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EEs' tools & toys

Engineering humor is not an oxymoron

Confident that engineers are not a bunch of nerdy bit jockeys, with calculators where other people have funny bones, Oak Ridge Public Relations Inc. is compiling a book of high-tech humor, to be called *The Book of High Tech Humor.* To that end, the agency is soliciting technical jokes of all genres: riddles, one-liners, puns, shaggy dog stories—the lot. It promises (or maybe threatens) to credit all contributors unless they insist on remaining anonymous.

Clearly tuned in to the world of technology, Oak Ridge is vague on timing. "The product is still in development," said Kathy Keenan, who styles herself Empress of the Universe at Oak Ridge. "We expect to be through beta by the third quarter, and to ship in Q4." The agency plans to distribute single copies of the book free of charge when it is published.

Submissions to *The Book of High Tech Humor* may be mailed in or faxed. *Contact: Oak Ridge Public Relations Inc., 21771 Stevens Creek Blvd., Suite 203, Cupertino, Calif. 95014-1175; fax, 408-253-0936.*

POWER AND ENERGY

Starting three-phase motors...

...is a complex business. Choices must be made among line, reduced-voltage, and reduced-frequency starting, not to mention mechanical and solid-state starters.

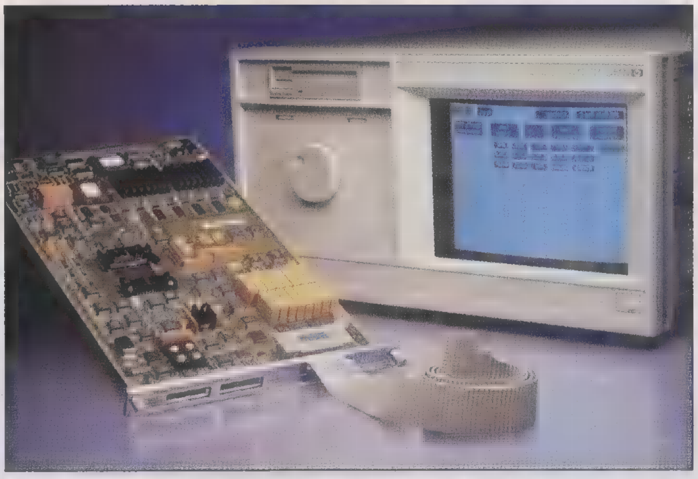
To help designers choose the best starting system for each application, Firing Circuits Inc. has published a booklet entitled "Understanding Motor Starters," which describes the advantages and limitations of various starting systems. The booklet also includes a brief catalog of the company's Wattstop family of microprocessor-controlled, solid-state, reduced-voltage starters.

The booklet is available free of charge. *Contact: Firing Circuits Inc., Muller Avenue, Box 2007, Norwalk, Conn. 06852; 203-846-1633; fax, 203-846-9293; or* **circle 101.**

INSTRUMENTATION

Logic analyzer gets deep memory

Recognizing the increasing importance of image-processing applications, with their enormous data requirements, Hewlett-Packard Co. has developed a deep-memory data-acquisition card for its 16500A logic analysis system. The HP 16542A card contains 2M bytes of memory; it can be configured as either a 16-channel card with 1M bit behind each pin or as an eight-channel unit with 2M bits of memory depth.



Up to five of the HP 16542A deep-memory data-acquisition cards [front] can be plugged into a 16500A system mainframe [rear] to provide up to 10M bits per channel for eight channels or 1M bit per channel for 80 channels.

Up to five cards may be plugged into a single 16500A mainframe in four configurations. The maximum-depth configuration provides 10M bits behind each of eight channels. The maximum-width arrangement is 80 channels wide and has a depth of 1M bit. The two remaining possibilities are 16 channels by 5M bits and 40 channels by 2M bits.

In addition to image processing, the 16542A is expected to prove useful for cache hit/miss analysis, testing complex application-specific ICs (ASICs), and troubleshooting systems with intermittent failures. Often, the conditions that lead to such failures occur far in advance of the system crash: hence the need for deep memory.

The HP 16542A lists for US $8500 and has an estimated delivery time of eight weeks. (The 16500A mainframe into which it plugs is priced at $7700.) *Contact: Hewlett-Packard Co. Inquiries, 19310 Pruneridge Ave., Cupertino, Calif. 95014; 800-452-4844; or* **circle 102.**

Handheld scope calibrator

Although it weighs only 0.27 kg and fits into the palm of a hand, the PRL-150 100-MHz time mark pulse generator is a precision instrument that checks such critical scope functions as time-base accuracy, vertical amplifier gain, rise time, and probe compensation. The unit also provides 50-Ω drive levels for testing high-speed TTL, CMOS, and emitter-coupled logic (ECL) circuits.

Key specifications of the generator include a frequency accuracy of 0.01 percent and a total of 151 time markers, from 10 ns to 160 seconds. The time marker output can deliver three switch-selectable levels: TTL/CMOS, ECL, and ±2.5 V open circuit (±1.25 V into 50 Ω) with a rise time of less than 1 ns. A second output generates either a 0.2 percent 5-V dc level for verifying vertical amplifier gain or a 5-V 1-kHz square wave for adjusting probe compensation.

The PRL150 sells for $597 in small quantities. A stripped-down version with only a 50-Ω TTL time marker output is also offered. Called the PRL155, the latter is priced at $385. Both of the units are available from stock. *Contact: Pulse Research Lab, 1536 West 25th St., San Pedro, Calif. 90732; 310-515-5199; fax, 310-515-0068; or* **circle 103.**

This $597 instrument can verify such critical oscilloscope functions as time-base accuracy, gain, and rise time. It also stands in for much more expensive generators when continuously variable frequency and pulse width are not required.

Economical e-beam lithography

Electron-beam lithography is expensive, with production e-beam writers going for upwards of $2 million. But researchers with access to an electron microscope and with no need for commercial production writing

rates can save themselves a bundle while producing lines as fine as 0.02 μm.

How? With a PC-based electron microscope add-on called NPGS (for nanometer pattern generation system). The complete NPGS package comprises everything needed to make an electron-beam pattern-generating system except the microscope.

It includes a Compaq 386SX/20 computer with MS-DOS 5.0, a Data Translation 16-bit multifunction board, a custom beam-blanking timing board, NPGS software, DesignCAD software (for pattern layout), documentation, installation on the microscope, and user training—all for $42 000.

For users who prefer to acquire the computer and Data Translation board elsewhere, and can install the equipment themselves, a so-called University Version is available for only $22 000.

The NPGS requires no modifications to the electron microscope with which it is used. Hence the scope remains available for normal viewing. Indeed, it is frequently used to examine patterns just made by the NPGS. *Contact: JC Nabity Lithography Systems, Box 5354, Bozeman, Mont. 59717; 406-585-4001; or* **circle 105.**

EDUCATION

Kit clarifies fuzzy logic

Heard about fuzzy logic but don't know exactly what it is or whether you should be using it? An inexpensive educational kit from Motorola Inc. may be a big help. It contains a computer-based introductory course (on both 5.25- and 3.5-inch disks), an introductory version of Motorola's fuzzy inference development environment (FIDE, pronounced feeday), and a collection of fuzzy logic freeware with documentation. FIDE was recently announced in conjunction with software developer Aptronix Inc. of San Jose, Calif.

The course guides the novice step by step through ■ typical fuzzy logic design cycle, helping users determine the correct membership functions and rules for their application. An English-like data entry language enables ■ system to be described in ordinary functional terms. And a composer lets users tie fuzzy and nonfuzzy modules together. The modules can be linked either graphically, as a kind of data flow chart, or textually.

The course enables engineers to implement fuzzy logic solutions using, naturally enough, standard microcontroller parts from Motorola. A built-in code generator produces code for the HC05 and HC11 families of microcontrollers.

Minimum requirements for running the course include a PC/AT-class computer, ■ high-density floppy drive, ■ 40-Mbyte hard drive, ■ VGA monitor, DOS 3.30 (5.0 recommended), and Windows 3.0.

The kit (designated FLEDKT00) is being offered at an introductory price of $195, which is scheduled to rise to $295 on Sept. 1.

For $600 more, purchasers of the kit may also buy an in-circuit emulation package containing either an M68HC05EVM emulator (FLEDKT05) or else an M68HC11EVM (FLEDKT11). The emulation packages are introductory products only and will be discontinued at the end of August. They are not required for completing the fuzzy logic course. For people who want to plunge right into fuzzy logic development, ■ full version of FIDE is also available for $1495. *Contact: FLEDKT, Motorola Inc., Box 1466, Austin, Texas 78767; Jack Davis, 512-891-2840; or* **circle 104.**

To supplement the fuzzy logic educational kit, Motorola is also offering emulation kits for its 68HC05 and 68HC11 families of microcontrollers.

SOLID STATE

One-stop light-to-voltage sensing

Typically, when an application requires interfacing a light sensor with a voltage-input device like a comparator or ■■ analog-to-digital converter, it is necessary to convert the light sensor's current output into a voltage. Now, with the TSL250 from Texas Instruments Inc., that conversion is purchased in with the sensor. The TSL250 combines ■ large-area silicon photodiode with an operational amplifier and feedback components to form a complete light-to-voltage sensor-on-a-chip.

The TSL250 has just three terminals—power, ground, and output. It senses both infrared and visible light, responding to wavelengths of 350–1050 nanometers. Typical specifications include a dark voltage of 3 mV, a supply current of 800 μA at a supply voltage of 5 V, and a linear response from 50 mV to 3 V.

The TSL250 is suitable for applications such as lighting control, gas- and oil-burner flame monitoring, security systems, infrared remote control, and medical chemical testing. A sample and documentation are available. *Contact: Texas Instruments Inc., Box 809066, Dallas, Texas 75380-9066; or* **circle 106.**

CATALOGS

Microwave parts by the score

An extremely accurate laser piston attenuator for use at 1.25 MHz and 30.0 MHz is the star of the latest catalog from Weinschel Associates. The attenuator, the PA-4B, has a maximum incremental insertion-loss error of $\pm$(0.001 dB/10 dB + 0.0005 dB) between 15 and 115 dB. It measures insertion loss to within 0.0001 dB.

In addition to the PA-4B, the catalog gives details of a broad range of fixed and variable attenuators, terminations, power splitters, attenuator sets, ■ double-stub tuner, and ■ slotted line. Among the covered devices are high- and medium-powered attenuators and terminations, most of which operate from dc to 18 GHz, with some going up as high as 40 GHz.

The catalog includes two conversion charts: one for power ratio and decibels, and the other for standing-wave ratio, return loss, and reflection coefficient. It is available at no charge. *Contact: Weinschel Associates, 42 Cessna Court (Airpark), Gaithersburg, Md. 20879; 301-948-8342; fax, 301-869-9783; or* **circle 107.**

Data-acquisition boards and more

A complete line of data-acquisition boards, instruments, and software is detailed in a 130-page catalog from IOtech. The book provides information on boards for use with IBM-PC–type computers, Macintoshes, and workstations from Sun, DEC, and NeXT. It also describes RS-232 controllers and modems that facilitate connection to just about any type of computer currently on the market. In addition, it covers IEEE 488.2 bus controllers, analyzers, extenders, buffers, and converters.

The catalog includes ■ brief tutorial section on the IEEE 488 instrumentation bus standard and the more recent SCPI (Standard Commands for Programmable Instrumentation) standard, which describes standard ways to use the bus. For users who need more than a brief tutorial on the IEEE 488 bus, IOtech has put together two seminars—one for beginners and one for more advanced users. Both are offered at no charge for presentation at the user's facility. Details are in the catalog, which is available for free. *Contact: IOtech Inc., 25971 Cannon Rd., Cleveland, Ohio 44146; 216-439-4091; fax, 216-439-4093; or* **circle 108.**

COORDINATOR: Michael Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

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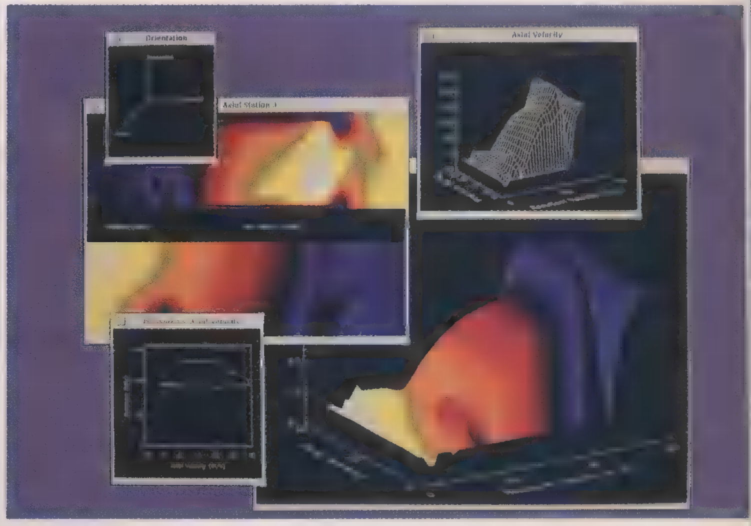

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Circle No. 26

The engineer at large

U.S. jobs in electronics continue their slide

The number of jobs at U.S. electronics companies shrank by 1.7 percent, or 40 000, in the first quarter of 1992, according to the American Electronics Association (AEA). This is over and above the 90 000 jobs that the AEA calculated were lost during all of last year.

"It is rapidly becoming apparent that this pattern is not of short-term duration and not wholly the result of the recent recessionary period," said J. Richard Iverson, president and chief executive officer of the AEA, which represents some 3000 companies throughout the United States. "Not one of the past 10 quarters has demonstrated the job growth typical of our industry."

During the first quarter of 1992, the most jobs—9100—were lost at computer makers. Next came makers of communications equipment, which lost 7200 jobs, followed by makers of search and navigation equipment with 7000 jobs. At the end of the quarter, the total number of jobs in the electronics industry was put by the AEA at 2.35 million.

Electronics employment was also down 100 000, or 4.1 percent, from the March 1991 level of 2.45 million. That meant employment was at its lowest level in more than eight years (year-end unemployment in 1983 was 2.38 million, and the peak was 2.6 million in August 1989).

Software jobs suffered, too. For the first time since the AEA began tracking that sector in 1985, employment failed to grow, remaining flat during the first quarter at 133 400. However, it had reached that figure in December 1991 by way of a hefty 14 percent jump for the year, the only industry segment that did not decline during 1991, according to the AEA.

Figures are AEA estimates based on data provided by the U.S. Bureau of Labor Statistics and are subject to later revision.

Median EE income = US $58 000

The 1990 median income of U.S. members of the IEEE, who are employed full-time in their primary areas of technical competence, was US $58 000, according to a salary survey by IEEE U.S. Activities. As for 1991 starting salaries for electrical engineers, the median ranged from $32 000 in government to $35 500 in companies employing 10 000 or more.

The document also noted that in 1990, "some period of involuntary unemployment averaging 17 weeks" fell to the lot of almost 6 percent of respondents. The 128-page 1991 *IEEE Membership Salary & Fringe Benefit Survey* provides salary information for engineers employed in all areas of electrical and electronics technology, including aerospace, computers, and communications, as well as biomedicine, electric power, and consumer electronics.

Other survey conclusions regarding 1990 incomes were that:

- The median income in 10 major areas of technical competence ranged from a low of $54 000 in systems and control to a high of $66 800 in engineering and human environment. In computers, which had most respondents, medians were $55 000 for software and $56 000 for hardware.
- The largest income by industry in 1990 was communications' median figure of $62 000.
- Consultants had the top reported incomes, with more than 10 percent of their salaries exceeding $101 400.
- State and Federal employees reported the lowest median income—$52 000; respondents at companies with 10 or fewer employees earned the highest median income—$65 000.
- Registered professional engineers responding to the survey reported a median income of $62 000, or $4000 more than the median for all EEs working full-time.

As documented in earlier surveys, income rises with up to 20 years of experience but stabilizes around $70 000. The research also showed that 1990 entry level income for women was about the same as for men, though after 10 to 19 years' experience earnings lagged by as much as $6000.

The survey drew a 10 percent sample (every 10th name) from the IEEE-USA membership list of 210 561 nonstudent U.S. members. A total of 6946 surveys were returned from the 21 000-plus sample, for a return rate of almost 34 percent. The 1991 IEEE *U.S. Membership Salary Survey*, Catalog No. UHO185-9, is available to members for $74.95 and to nonmembers for $99.95. *Contact: IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 088556-1331; 800-678-IEEE.*

Going private

Engineers employed by public agencies in the United States may be caught up in an unusual type of privatization, thanks to an executive order recently signed by President George W. Bush. The aim is to promote the development and refurbishment of the country's infrastructure by the private sector.

Accordingly, the order instructs Federal agencies to assist state and local governments "in advancing appropriate privatization transactions." In other words, the agencies are to help municipalities sell to private interests entities that heretofore usually belonged to the public—roads and bridges, mass transit and railroad systems, airports, public housing, and wastewater and solid-waste treatment plants.

Engineering enrollments hold

Although the short-range outlook for placement in engineering jobs has not been encouraging, undergraduate engineering and technology enrollment held up "very well last fall," according to a survey done by the Engineering Manpower Commission of the American Association of Engineering Societies (AAES), Washington, D.C. The overall number of full-time undergraduates increased by less than two-tenths of 1 percent, or 555 students, over the previous year, to a total of 339 397. However, first-year engineering enrollments declined a relatively mild 1.4 percent last fall to 93 002.

Both full-time and first-year undergraduate enrollments declined in the fields of electrical, computer, aerospace, industrial, management, and manufacturing engineering. The enrollments did go up in chemical, petroleum, civil, and environmental engineering. And proportionally more women enrolled in freshman engineering programs in 1991, breaking the 18 percent mark for the first time.

The commission gained its figures by surveying engineering enrollments at 336 institutions. These and other results are examined in *Engineering and Technology Enrollment*, Fall 1991. The book is US $120 for AAES members, $195 for nonmembers; it is also available on disk. *Contact: AAES Publications, 1111 19th St., N.W., Suite 608, Washington, D.C. 20036-3690; 800-658-8897.*

Who spins the wheels?

Countries with a higher ratio of engineering students to law students have higher economic growth. That was the conclusion of two economists, Kevin Murphy of the University of Chicago in Illinois and Andrei Shleifer of Harvard University, Cambridge, Mass., after correlating the numbers of engineering and law students in 55 countries from 1970 to 1985.

In most cases during these 15 years, when a country had more students studying engineering, its economic growth rate was higher than when it had more students

studying law. According to the findings, if the United States doubled the number of its engineering students, its growth rate might increase by an average 5 percent; doubling the number of law students might cause growth to drop by 3 percent.

What to learn next

To Donald E. Petersen, former chairman of the board and chief executive officer of Ford Motor Co., it goes without question that an engineer must continue learning throughout his or her career—and today the demand is for a blend of optics, mechanics, and electronics.

Petersen himself received a bachelor's degree in mechanical engineering from the University of Washington, Seattle, in 1946 and did what he calls his first "cross-over" only three years later by obtaining a master's degree in business administration from Stanford University. Thus equipped, he could deal with two parts of the corporate system when he joined Ford, he pointed out in a recent article in *The Bent of Tau Beta Pi*, the quarterly published by the college honor society (Spring, 1992, p. 20).

Intrigued by the auto industry's diverse disciplines, Petersen writes that he kept on crossing over, using every opportunity to learn about matters like computers and manufacturing that fell outside his current job. In the 1970s, the blending of computers and electronics with the mechanical engineering ethos of the auto industry grew into a discipline Petersen calls mechatronics. Ford helped develop a mechatronics-oriented master's degree program for its engineers at Wayne State University in Detroit, Mich. Such courses and departments have since spread elsewhere, he points out in his article.

Now, in the early '90s, Petersen sees an analog of the mechatronics of the '70s: optomechatronics. Videocassette recorders and compact-disc (CD) players are the most common examples. According to Petersen, optomechatronics could be today's focus for an engineer's lifelong learning program.

PEs [illegible] liability protection

In cases of natural disasters, such as hurricanes or floods, professional engineers helping to deal with the destruction may encounter a problem outside the ravages of wind or water: are they exposing themselves to future lawsuits?

Certainly, the explosion of liability lawsuits in the United States creates a fertile area of concern. In 1989, for example, after Hurricane Hugo ripped through Charleston, S.C., 100 engineers from the South Carolina Society of Professional Engineers (SCSPE) volunteered their services to the state.

"It took the governor's office a day or so to figure out a way to utilize the engineers' services and at the same time protect them from any liability," said SCSPE executive director Joe Jones. The solution was to make the volunteers temporary state employees to shield them from litigation so they could go to work.

While all 50 states offer Good Samaritan protection to individuals assisting the injured in emergencies, only six of them offer liability protection specifically to engineers. Virginia was the most recent one to start doing so; it passed legislation this spring. The other states are California, Tennessee, Utah, Connecticut, and Missouri.

This winter, the National Society of Professional Engineers, which represents more than 75 000 registered engineers from all technical disciplines, gave its appproval to model Good Samaritan legislation. And the South Carolina chapter was the first state engineering society to introduce this model law in its entirety before a state legislature. The South Carolina legislature, in fact, declined to pass it at its most recent session, but could consider the matter again another time.

COORDINATOR: Alfred Rosenblatt

Global mobile satellite communications

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This new appointment offers a degree-level engineer with experience of satellite link design and intersystem interference calculations, and a good knowledge of the ITU and radio regulations, an excellent opportunity to join Inmarsat's headquarters team in London.

An internationally-owned co-operative backed by 64 member countries, Inmarsat is a world leader in the provision of global mobile satellite communications for commercial and distress and safety applications at sea, on land, and in the air.

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You would join the Spectrum Management Group and provide support in all areas associated with frequency planning and co-ordination and the sharing of the radio spectrum with other users.

With 51 nationalities working in our London office, we can offer an unusually cosmopolitan environment. An internationally competitive tax-exempt salary reflects the high level of competence, experience and qualifications we require. Employment terms include: * non-resident's allowance * housing allowance * children's school fees * fares home for staff member and family every 2 years * spouse career counselling * 5 weeks' annual leave * all relocation costs paid on appointment and resettlement * worldwide health, life and accident insurance * 100% cash pension. Indefinite or fixed-term contract available. All necessary clearances for working in the UK are arranged by Inmarsat.

To apply, please fax or mail full career details in English, quoting **Ref: SFCE/MS** on the letter and envelope, to Mike Stockford,
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London SW1W 9SR, England.
Facsimile: ++4471 333 5050.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

ADVERTISING RATES

Positions open—$36.00 per line, not agency-commissionable

Positions wanted—$36.00 per line, a 50% discount for IEEE members who supply their membership numbers with advertising copy

All classified advertising copy must be received by the 25th of month, two months preceding date of issue. No telephone orders accepted. For further information contact Francesca Silvestri, 212-705-7578.

IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

BellSouth Eminent Scholar's Chair in Electrical Engineering. The Department of Electrical Engineering at the University of Florida invites nominations and applications for an endowed, chaired professorship in the general field of telecommunications. The Department of Electrical Engineering is the largest department in the University of Florida with 518 undergraduates and 375 graduate students. The department is ranked 21st of more than 250 Electrical Engineering undergraduate programs. The Electrical Engineering faculty is comprised of fourteen IEEE Fellows, two members of the National Academy of Engineering, one of whom holds an endowed chair in Microelectronics. The College of Engineering is ranked 17th nationally based on its funded research programs. For the BellSouth Chair, we seek a researcher and teacher of great distinction, whose work has been internationally acclaimed. Proceeds from an endowment and additional resources will provide an environment commensurate with the excellence of the person sought. Nominations and applications should be sent to Professor Donald G. Childers, Chairman, BellSouth Chair Search Committee, Department of Electrical Engineering, 405 CSE, University of Florida, Gainesville, FL 32611-2024; telephone (940) 392-2633. The application deadline is August 1, 1992. The University of Florida is an Affirmative Action Employer and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request.

University of Wisconsin-Madison Faculty Position. The Department of Electrical and Computer Engineering invites applications for a tenure or tenure-track faculty position. A Ph.D. degree is required, and the successful candidate is expected to have strong emphasis and interest in electronic circuits and to develop a research program in an electronics-related area, such as power electronics, VLSI circuits for signal processing, computer aided analysis and design of electronic circuits, high-frequency or microwave electronic circuits, or biomedical electronics. Rank and salary will be commensurate with qualifications and experience. Send resume and names of three references to Bahaa E.A. Saleh, Chairman, Department of Electrical and Computer Engineering, University of Wisconsin-Madison, 1415 Johnson Drive, Madison, WI 53706, an equal opportunity/affirmative action employer. Names, titles and/or occupations, and addresses of applicants and nominees cannot be kept confidential.

Associate Development Engineer to design program specifications for intelligent CAD-CAM system with graphic interface and to transfer and modify as necessary, existing prototype software into different hardware and software platforms. Requires Ph.D. or equivalent in computer science; at least two years in the job offered or two years research experience in advanced CAD-CAM software implementation. Demonstrated ability in developing software in various languages (including Assembler, Fortran, C and Prolog) and on various computer platforms (including personal computers, workstations, mainframes, and super-computers). Experience in CAD system design and production process simulation, applicable to intelligent manufacturing CAD system development. Working knowledge of modern applied algebra, logic and theory of algorithms, and experience in heuristic solution of sophisticated NP-complete problems. $43,500 per year. Job location/interview: Los Angeles, California. Send this ad and your resume of qualifications to Job # BLW9620, P.O. Box 9560, Sacramento, CA 95823-0560, no later than July 31, 1992.

Position Open: The Dept. of BME of the University of Miami seeks applications and nominations for a new tenure track faculty position at the Asst. Prof. rank, for the Fall '92 semester, with the following minimum qualifications: PhD in Engineering or in a closely allied field; research experience in BME; demonstrable interest in the development and teaching of undergraduate level lecture and lab courses in BME. The 9-month appointment may be extended for summers. Salary and fringe benefits are competitive. The University of Miami is an equal opportunity employer. Please contact: Dr. Ozcan Ozdamar, Dept. of BME, College of Engineering, University of Miami, POB 248294, Coral Gables, FL 33124.

Electrical & Systems Engineering—Faculty Search. The Electrical and Systems Engineering Department at the University of Connecticut invites qualified candidates to apply for an anticipated, tenure-track Associate/Full Professor position. A doctoral degree in Electrical/Systems Engineering or in a closely related field and training/experience as an electrical engineer are required. Professional experience in a number of the following areas is essential: optical systems engineering, laser assisted precision manufacturing, optical sensors and metrology, and optical communication systems. Required duties include teaching at the undergraduate and graduate levels, obtaining external funding and performing research in the candidate's area of expertise, and supervising graduate student research. Funded program development and management experience will be given special consideration as the position may require leadership role in the Photonics Research Center at the University. Starting salary will be commensurate with the candidate's qualifications. The University of Connecticut is the flagship state institution located in a beautiful rural area within easy reach of Boston and New York City. Please mail application and resume to: Chair, Faculty Search Committee, Electrical & Systems Engineering Department, The University of Connecticut, U-157, 260 Glenbrook Road, Storrs, CT 06269-3157. The University of Connecticut is an Affirmative Action/Equal Opportunity Employer. (Search #2A150).

Concordia University—Electrical and Computer Engineering. The Department of Electrical and Computer Engineering at Concordia University invites applications for a tenure-track faculty position at the Assistant or Associate Professor levels. Applicants must have a Ph.D. in Electrical or Computer Engineering, and a commitment to teaching at undergraduate and graduate levels and pursuing independent research. Industrial and research experience is desirable. We are primarily searching for candidates with teaching interests and demonstrated research expertise in the general area of signal processing with an emphasis on one of the following: digital signal processing, array signal processing, multidimensional signal processing, spectrum estimation and hardware modelling. Preference will be given to those with hardware experience. The candidate will be welcome to take part in the joint research work undertaken by faculty members working together in the "Center for Signal Processing and Communications". The department currently has 24 full-time faculty members and is strongly committed to research excellence. The department offers bachelor's programs in Electrical Engineering and Computer Engineering, and Master's and Doctoral programs in Electrical Engineering. There are currently over 150 graduate students, of whom approximately 50 are doctoral students. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. Concordia University is committed to employment equity and encourages applications from women, aboriginal people, visible minorities and disabled persons. All things being equal, women candidates shall be given priority. Applications will be accepted until the position is filled. Applicants should send a resume and names of at least three references to: Dr. P.D. Ziogas, Chairperson, Department of Electrical and Computer Engineering, Concordia University, 1455 de Maisonneuve Blvd., West, Montreal, Quebec, H3G 1M8, Canada.

Auburn University—Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Nominations and applications are invited for the Earle C. Williams Eminent Scholar Chair in Electrical Engineering. Candidates for this chair should have achieved national and international prominence in digital systems and/or microelectronics. Applicants or nominees must have an earned doctorate, senior academic experience, and a documented record of distinction in university teaching and research. The successful candidate will be expected to provide intellectual leadership in his/her area of expertise for the Department of Electrical Engineering as well as enrich the scholarly environment at Auburn University. Auburn University is located in the city of Auburn in east-central Alabama. This land-grant university enrolls more than 21,000 students, the largest on-campus enrollment in the state. The Department of Electrical Engineering, one of eight departments within the College of Engineering, offers Bachelor, Master, Master of Science and Ph.D. degrees in Electrical Engineering. The department has a current enrollment of 939 undergraduate students and 100 graduate students. The 28 full-time faculty have an annual research expenditure of approximately $2 million. The Search Committee will begin its review of applications immediately. Interested candidates should submit: (1) a detailed resume, (2) a letter indicating an interest in the chair, the candidates's academic philosophy, and a brief statement of accomplishments in teaching and research, and (3) names and addresses of five references. Nominations should be submitted with the complete name, mailing address and telephone number of the individual nominated. Applications and nominations should be sent to Professor J. David Irwin, Department of Electrical Engineering, Auburn University, AL 36849-5201. Auburn University is an affirmative action/equal opportunity employer. Applications from minority and female candidates are encouraged.

The University of Melbourne, Australia—Chair of Computer Engineering. The University of Melbourne invites applications for a Chair of Computer Engineering which has been established in the Department of Electrical and Electronic Engineering. The Department together with the Department of Computer Science, forms the School of Information Technology and Electrical Engineering. The Department has extensive teaching and research programs in electrical and electronic engineering. Its research activi-

ties include software reliability, computer architecture and networking, distributed processing, photonics, communications, signal processing, control and biomedical engineering. The successful applicant will have a distinguished record of professional achievement and will be committed to developing an active research and teaching program. It is anticipated that the successful applicant will form strong research links with industry. A base salary is $A73,800 per annum on appointment and will rise to $A77,900 from July 1992. Further information about the position, application procedures, conditions for outside work, superannuation, travel and removal expenses, housing assistance and conditions of appointment, is available from the Registrar. All correspondence (marked "Personal and Confidential") should be addressed to the Registrar, The University of Melbourne, Parkville, Victoria, 3052, Australia. Telephone (613) 344-7529 (Ms. Kaye Goldenberg). Facsimile (613) 344-6897. Applications close on 30 September, 1992. The Council reserves the right to make no appointment or to fill the Chair by invitation at any stage. The University of Melbourne is an equal opportunity employer and has implemented a smoke-free work-place policy.

Graduate Research Assistants: The University of Virginia Semiconductor Device Laboratory is seeking exceptional students for Ph.D. studies. Several full fellowships (tuition and fees, plus stipend) are available for qualified students (U.S. citizens and/or permanent residents). Research areas include a-Si material and devices, superconducting electronics fabrication, and investigation and fabrication of submicron GaAs Schottky devices for THz applications. Prospective students must be highly motivated and have exceptional qualifications, prior research experience is highly desirable. Please send resumes to: Dr. M. Shur, Dept. of Elec. Engr., Thornton Hall, Univ. of Virginia, Charlottesville, VA 22903. Female and underrepresented minority applications are highly encouraged. The University of Virginia is an equal opportunity/affirmative action employer.

The Swiss Federal Institute of Technology Zurich (ETHZ) is looking for an Assistant Professor of Engine Electronics. Duties of the new professor include research and teaching (fundamentals and applications) in electronics and electronic control of internal combustion engines' systems. Candidates must have a university degree as well as professional experience in the area of electronics, electronic control, computer sciences and thermodynamics. They should have a particular interest in working in the highly interdisciplinary field of electrical and mechanical engineering. The post of an assistant professor has been established to further the career of younger scientists. It is available for three years in the first instance, and renewable for another three years, and offers a scientist with outstanding accomplishments the opportunity to be promoted to the rank of an associate professor (tenure track). Please apply with a curriculum vitae, a list of publications and a record of projects, by July 31, 1992, to the President of ETHZ, Prof. Dr. J. Nuesch, ETH Zentrum, CH-8092 Zurich. The ETHZ specifically encourages female candidates to apply with a view towards increasing the proportion of female professors. For further information please contact Prof. Dr. M.K. Eberle, Institute of Energy Technology, ETH Zentrum, CH-8092 Zurich (phone 1-256 2474, fax 1-262 5207).

Postdoctoral Research Associate. Carnegie Mellon University. Applications are encouraged from those with experience in fluidization. Knowledge of computer programming and numerical methods is required. Starting date is flexible for the Summer or Fall of 1992. Depending on qualifications, salary is negotiable. Extension of appointment beyond one year is possible. Candidates must have a Ph.D. Send full resume and a list of three professional references to Jennifer L. Sinclair, Department of Chemical Engineering, Carnegie Mellon University, Pittsburgh, Pa 15213. CMU is an Affirmative Action/Equal Opportunity Employer.

University of California, San Diego. The Optical Information Processing Group in the Department of Electrical and Computer Engineering is seeking a qualified candidate to fill the position of Assistant Research Physicist—I. The position involves research in the applications of photorefractive crystals to optical computing and holographic memory, design and packaging of opto-electronic computing systems and neural networks. Applicants must have a Ph.D. degree in Electrical Engineering or equivalent discipline. The position also requires at least six months experience and a publication record in the areas described above. Salary will $41,600 per annum based on UC salary scales. A resume and the names of at least three references should be sent no later than July 31, 1992 to Professor Sing H. Lee, Department of Electrical and Computer Engineering, 0407, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0407. Immigration status of non-citizens should be stated in the dossier. The University of California is an equal opportunity/affirmative action employer.

Computer Science—The EE Department of the University of Technology, Hamburg-Harburg, invites applications for a full professorship in the following area: Operating Systems (distributed operating systems, fault tolerant operating systems, real time operating systems). The university is highly research oriented, welcomes cooperation with industry and puts stress on qualified individual education. The Department offers programs leading to the Dipl.-Ing. and Dr.-Ing. degrees. Applicants must have a Ph.D., proven teaching ability and a high research reputation and should send their resume and the names of three references to: Prasident der Technischen Universitat Hamburg-Harburg, SchloBmuhlendamm 32, W-2100 Hamburg 90 (FRG). The University of Technology of Hamburg-Harburg is an equal opportunity employer.

Electrical Engineering: FAMU/FSU College of Engineering, Tallahassee, FL. Visiting Assistant Professor position for 1992-93 academic year. Will consider most areas except electromagnetics. Submit resume and references to Dr. T.J. Harrison, Dept. of Electrical Engineering, P.O. Box 2175, Tallahassee, FL 32316.

Government/Industry Positions Open

Engineer, Senior Process. Develop sophisticated manufacturing processes for new generation microprocessors; develop novel Rapid Thermal Processor module associated with submicron CMOS/BiCMOS VLSI fabrication process; plan & implement laboratory operations to develop material & fabrication procedures; evaluate technical & economic factors to attain design objectives. Ph.D. in Materials Science, Physics or Electrical Engineering. Academic project/research background in thin film device fabrication, characterization & analysis, including absorption & emission characteristics of semiconductor thin films, submicron CMOS VLSI fabrication & processing, thin film metallization, semiconductor chemistry & defect analysis, thin film analysis techniques, including vacuum technology, TEM & SEM, physical metallurgy and diffusion analysis for thin films, semiconductor solid state device physics & diffusion process modules, including RTP. $4,320/mo.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550308, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineer, Senior Process. Conduct development, pilot production & transfer to manufacturing of advanced metallization modules for VLSI circuits; perform wet chemical processing & metal defect reduction; install & characterize sputter system. Ph.D. in Materials Science and Engineering or Electrical Engineering. Academic project/research background in deposition & thin film growth of semiconductor materials, including physical, chemical & electrical characterization, metallization, sputter characterization, Ultra high vacuum equipment & techniques, VLSI fabrication, including clean room & IC fabrication of CMOS devices, physical analysis techniques, including X-ray diffraction, scanning electron microscope, transmission electron microscope & auger spectroscopy; academic coursework in semiconductor devices & electrical materials. $4,370/mo.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550304, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineer, Senior Device. Develop submicron transistor gate technology for logic circuits; investigate hot-carrier effects on submicron MOSFET devices & compare effect on single-mask & full-loop transistors; develop charge pumping system to localize interface traps & oxide-trapped charges to identify defects; conduct defect resolution. Ph.D. in Electrical Engineering. Academic project/research background in semiconductor device material processes & characterization, thin film growth, characterization & device defect reduction, model design for quantum devices, C-V measurement for device interface, epitaxial technology for device fabrication, electron diffraction, tunneling & hot carrier injection in nanometer devices, PC Basic programming & interfacing & bipolar heterojunction devices. $4,370/mo.; 40 hrs./wk. Place of employment and interview: Hillsboro, OR. If offered employment, must show legal right to work. Send this ad and your resume to: Job Order #5550310, 875 Union Street, N.E., Room #201, Salem, OR 97311. The company is an equal opportunity employer and fully supports affirmative action practices.

Research and Development Engineer wanted. Duties: Research, development, design and implementation of a controller for an induction motor drive system. Need a Ph.D. in Electrical Engg. Doctoral thesis must have been oriented towards control systems. Master's thesis and at least one publication on the topic of controller design and implementation for an induction and motor drive system. Pay is $50,490/yr. 40 hr/wk. Resumes to 7310 Woodward Ave., Rm 415, Detroit, MI 48202. Ref. #22192. Employer Paid Ad.

Engineer, Sr. Electrical System. Responsibilities: Developing a multi-transputer electronic system for automatic mechanical position & user interfacing for an advanced PCB drilling system. Responsible for recommending hardware/software & mechanical design solutions/performing end user support function/creating software for system & accuracy test/assisting mechanical engineers prove capabilities/dev. docs. Requirements: electrical engineer degree + 3 yrs or PHD in Electronics/Computer Science/Engineering + 3 yrs exp. or EEMS + 5 yrs exp. in EE & CS. Min. 22 units in CS. Graduage level training in parallel processing/comp. architecture & graphics/random process/communication/optimal signal processing & control. Substantial exp. in R&D of real-time adaptive signal processing & control in real-time analog/digital/microprocessor/A/D/D/A design/low-level programming & debugging (80X86 & transputer). Demonstrable knowledge in parallel processing/DOS/UNIX/Network/Graphics. Extensive OCCAM (TDS)/Parallel Fortran & C programming large multiprocessor system/data acquisition & database management/system packaging/analyzing & troubleshooting. Exp. in vibration/acoustic & noise control. Supervising/teaching exp. a plus. $50k/yr. Location/interview Torrance, CA. Send resume w/this ad to Job #ET3457, PO Box 9560, Sacramento, CA 95823-0560. No later than 7/31/92.

Electrical Engineer for Mftr in Batavia, OH: Conduct research and perform activities concerning design, manufacturing and testing of bimetallic and liquid in glass thermometers; manufacture and install equipments; develop applications of thermometers; design thermometers in accordance with contract specifications. Direct, coordinate and monitor activities and production to ensure they meet with customers requirements, maintenance and repair and to ensure effective and safe and products. Req'd 2 yrs college in Electrical Engineering, 4 yrs exp. 40 hrs/wk, 9am-5pm, Mon-Fri; $38,500/yr. Must have proof of legal authori-

CLASSIFIED EMPLOYMENT OPPORTUNITIES

ty to work permanently in U.S. Send resume in duplicate (no calls) to J. Davies, JO#1315050, Ohio Bureau to Employment Services, PO Box 1618, Columbus, OH 43216.

Engineer (semiconductor mfg.)-R&D for sputtering target materials & bonding tech., low loop bond wire, CFC eliminations & SEM/EDX analysis. Req. MS Mat. Sc & 1 yr adv. ed. or work exp. w/metallographic procedures, physical metallurgy, work piece failure analysis, elect. material & device fabrication, microelectronic defect engr, alloy process & testing mat. characterization; use of TEM/SEM & energy dispersive spectroscope. Jobsite/interview in Spokane, WA. Salary is $38,800/YR-40hrs/wk. Send resume to Employment Security Dept. E&T Div., Job #315012, P.O. Box 9046, Olympia, WA 98507-9046 before July 31, 1992.

Electrical Engr.—Conduct R&D in digital signal processing technologies for telephone switching systems. Apply linear & non-linear adaptive filtering techniques for speech coding & echo cancellation & equalization. Develop tree-structured algorithms & communication software suitable for real-time implementations in telephone switching systems. Knowl. of image processing, real analysis, stat. pattern recognition & stochastic processes in info. systems. Exper. with C. & Fortran on UNIX and MS-DOS. Rqmts: Ph.D. in Electrical Engr. and 1-1/2 yrs. exper. as Electrical Engr. or Research Asst. in Electrical Engr. field. M- F; 40 hr./wk.; 8:30-5:00; Sal: $51,000/yr. Mail resume & copy of ad to MD DEED, 1100 N. Eutaw St., Rm. 212, Balto., MD 21201; JO #9149413; Job Location: Clarksburg, MD.

Design Engineer, 40hrs/wk., 8:00am—5:00pm, $37,240/year. System design of infrared and linear camera quality inspection system for paper mills: prototyping of defect sampling and interface hardware on intel 286 or 386 machine platform; programming codes interactive with hardware and codes processing raw data with graphics theory using Borland C++ in MS-DOS environment; design of embedded 8051 family CPU board, motor control and other interface; design of ultrasonic ranging detector; redesign or modification of embedded 6800 family CPU board; technical support for manufacturing and field service. Tools: PM3580 Logic Analyzer; M68701EVM Emulator; OrCad SDT and PCB; Borland C++ and 6800 family Assembly. Master of Science in Electrical Engineering as well as two years experience as ■ Design Engineer or Research Assistant required. Previous experience must include: the Bus-like interconnection architecture for large-scale distributed computer systems; Inverse problem for detection systems; Graphics programming and software system simulation; Borland C++ and 8086 assembly. Graduate education must include one course each in: Advanced Microcomputer System; Random Signal Analysis; Advanced Combinatorics and Graphics Theory as well as one project each on peripheral control and image recognition. Must have proof of legal authority to work permanently in the U.S. Send two copies of your resume to: Illinois Department of Employment Security, 401 South State Street—3 South, Chicago, Illinois 60605, Attention: J. Aschenbrenner, Reference #V-IL-5092-A. No Calls. An Employer Paid Ad.

Senior Project Manager. Supervise a staff of 14 software engineers, analysts, and AI programmers responsible for the design and implementation of ■ model-based prototype system to assist crewstation designers in applying human engineering principles. This work at NASA Ames Research Center is focused on implementing integrated computational models of human performance, equipment, and environments of manned systems, for evaluation of crewstation designs. Requirements include 5-10 years project management experience in a research environment with 10 years software engineering experience, MS or PhD in CS/EE or Cognitive Science, thorough understanding of object-oriented architectures and programming techniques (Lisp/CLOS and/or C/C++), experience with project planning and control of large-scale software integration projects, excellent communication skills, both written and oral, and outstanding proven leadership and interpersonal skills, and a demonstrated ability to move research ideas and findings into practical applications. This assignment offers an opportunity to contribute to ■ state of the art human performance modeling effort in a stimulating research environment. Please send resume to: Sterling Software, 1121 San Antonio Road, Palo Alto, CA 94303, Department TM, EEO M/V/H/F.

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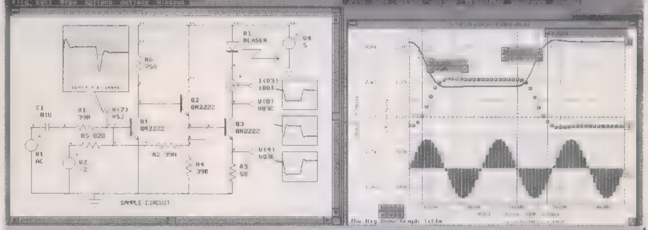

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For Buckley, the issues are technology and jobs

Calling the campaign so far for the U.S. presidency "a lot of fluff," IEEE President Merrill W. Buckley Jr. is trying to get the candidates to address the issues of technology and jobs.

"As President of the world's largest technical professional organization, I'm concerned about the survival of our high-tech workforce," Buckley said. "In the long run, I'm concerned about the United States' ability to function as a world power." (Buckley prefaced his remarks, made at a press conference in Washington, D.C., called by the IEEE-U.S. Activities Board, by saying that his comments were presented as those of a U.S. member.)

Among other points, Buckley challenged the candidates to say how they would:

- Ensure that industrial techology policy is integrated with national economic policy.
- Rejuvenate the U.S. electronics industry and restore jobs.
- Ensure that foreign acquisitions of U.S. high-technology firms will not threaten long-term U.S. competitiveness.
- Encourage long-term investment to revitalize U.S.-based manufacturing [THE INSTITUTE, July/August, p. 1].

Standards need global inputs

The IEEE standards department is embarking on a program to encourage IEEE members all over the world to get involved in writing standards. Accordingly, the department has developed several aids for encouraging such participation. One is a two-hour leadership training seminar for working groups who are writing or revising standards. It can be presented in any part of the world, and can be tailored to the needs of a specific working group. For more information, contact Mary Zweibel of the IEEE Standards Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3804; fax, 908-562-1571.

Another aid is a 15-minute videotape, "How To Develop a Standard," available to be shown at a meeting, and a list of speakers who are experienced in IEEE standards development. For more information, contact Karen DeChino at the address and fax number above, or call her at 908-562-3802 [THE INSTITUTE, July/August, p. 1].

Board streamlines amendment process

The Board of Directors voted at its May meeting to have an earlier deadline for receiving the text of proposed amendments. Proponents of changes to the constitution, beginning with the 1993 general election, must submit the wording of an amendment to IEEE Corporate Services by Jan. 15 of the year the amendment is to appear on the ballot. The new deadline will ensure that a legal review is performed before a lot of time is spent gathering signatures to qualify a proposition for the ballot.

Currently, proponents must submit the required number of signatures in late May, and legal review is performed sometime after. The Board may occasionally be in the position of having to oppose a proposition solely on the grounds that its wording renders it unlawful, when a slight change in wording could have reversed the situation.

Having legally approved wording will also make it more likely that petitions circulated in different areas will be identical [THE INSTITUTE, July/August, p. 12].

Coming
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COMPUTER SECURITY. This special report examines problems caused by malicious software and electronic eavesdropping, and suggests solutions. It also reports on clashes between government and industry/civil liberties groups in areas like the digital wiretapping of encoded communications. Finally, an international group of experts discuss current issues.

RELIABILITY AND THE DOD. Experts evaluate the pros and cons of Revision F of the Defense Department's *Handbook for Reliability Prediction*, already under fire for depending too heavily on purely statistical techniques.

WHAT'S UP IN SUPERCONDUCTIVITY. The Consortium for Superconducting Electronics is part of a White House effort to encourage the U.S. development of high-temperature superconductivity. In two years it has made progress in areas like thin films, microwave components, and Squids (superconducting quantum interference devices).

TRUSTWORTHY SOFTWARE. Software reliability means different things to the developer, tester, and user and must be measured from all points of view. A composite measure is being sought.

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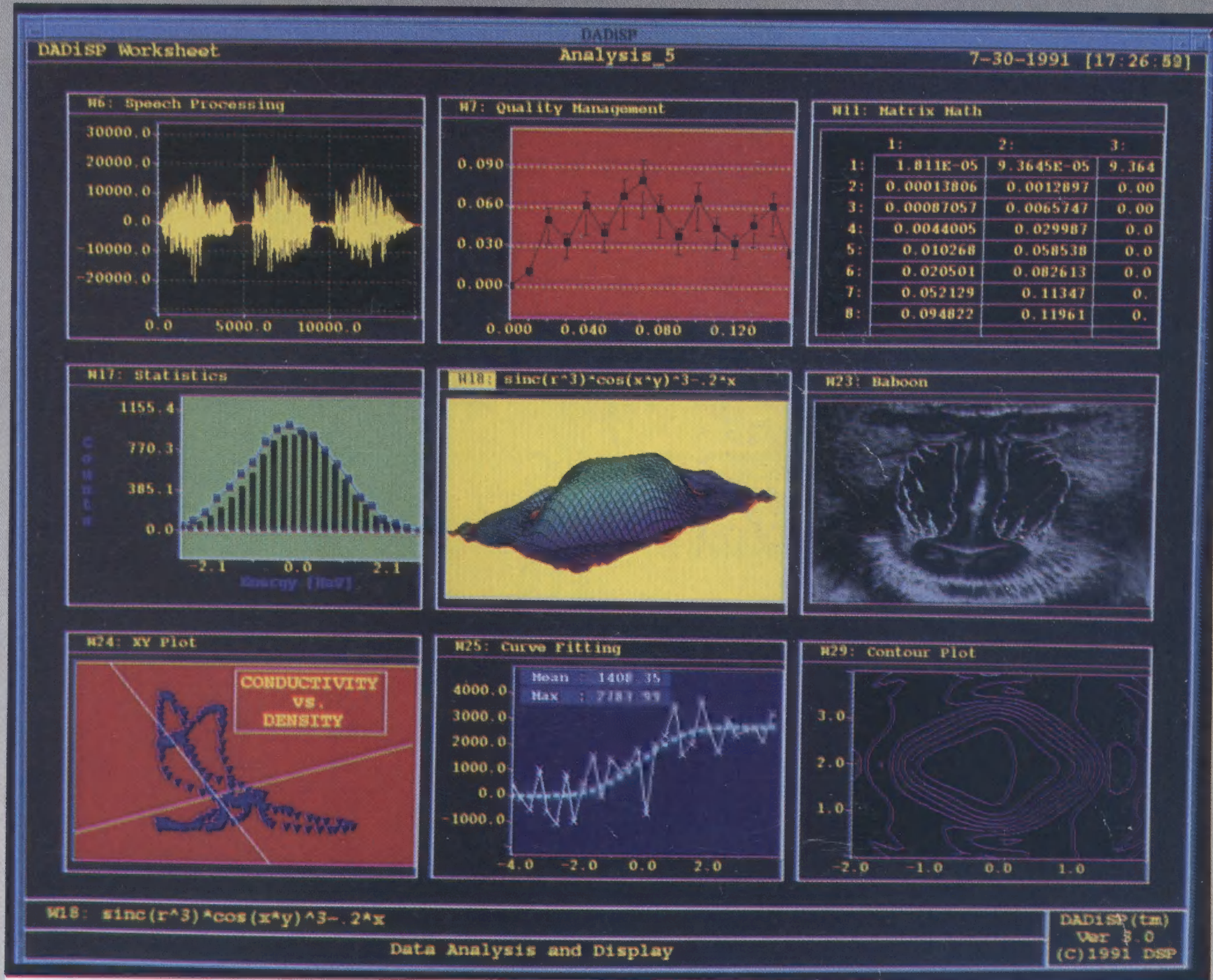

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